Monitoring and Management of a Sensitive Resource: A Landscape-level Approach with Amphibians

Final Report for FY 00

Legacy Resource Management Program Contract DACA87-99-H-0001
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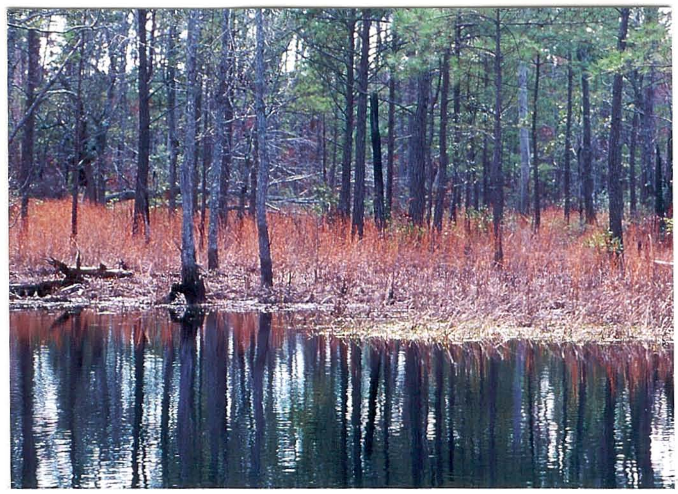
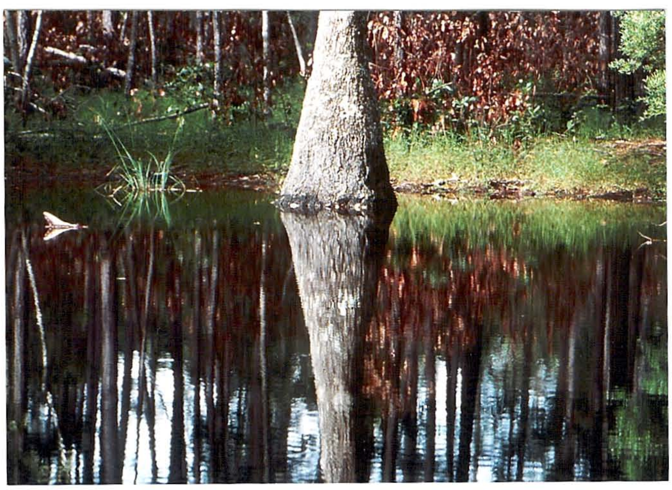


Principal Investigator:
Joseph C. Mitchell, Ph.D.
University of Richmond
Richmond, VA 23173

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Photos by R.W. Gaul, Jr.

EXECUTIVE SUMMARY

Development of effective integrated resource management plans that are realistic and ecosystem based requires detailed information on the dynamics of populations at the landscape level. Because amphibians are sensitive indicators of environmental change, understanding their population and community dynamics in fluctuating environments provides considerable insight into how resource managers can accomplish their mandates. This Legacy Resource Management Program project focuses on amphibian communities in three military installations in eastern North Carolina: Dare County Bombing Range (US Air Force), Cherry Point Marine Corps Air Station, and Marine Corps Base Camp Lejeune. This report summarizes the results of the second year of a three-year study.

The following objectives direct the study: (1) To develop a landscape-level methodology for assessing the dynamics of amphibian populations in federal installations in the eastern United States. This approach will provide information critical to the management of these sensitive resources from an ecosystem perspective, (2) To provide the quantitative baseline against which future assessments of amphibian populations and communities on each installation can be evaluated, (3) To provide installation personnel with the tools to monitor these sensitive organisms in the future so that population trends can be detected, and (4) To provide realistic management recommendations to each installation that will allow resource managers to reach their goals of maintaining viable populations of each species.

My field crew and I have used the following standardized techniques for two years to assess amphibians in terrestrial habitats: 300 meter-long artificial coverboard transects (30 coverboards) with 10 sections of PVC pipe set used to assess treefrogs. A total of 6 transects was installed at Cherry Point MCAS and Camp Lejeune (180 coverboards, 60 PVC pipe refugia each location), and 9 in Dare County Bombing Range (270 coverboards, 90 PVC pipe refugia). Transects were checked monthly (February-December) to assess amphibian use of these two types of refugia. The following standardized techniques were used to assess amphibians at wetlands: weekly nighttime assessments of calling frogs and monthly minnow trap and dipnet surveys for adults, tadpoles, and salamander larvae. The latter two wetland protocols were run February-October, and the frog call survey was run February-September when the frogs stopped calling.

During 2000 we captured 2,819 individual amphibians at Dare County Bombing Range, 1,767 Cherry Point, and 4,984 at Camp Lejeune, a substantial increase for all bases over 1999 captures. This report summarizes quantitative capture success for each technique in each of the three installations. Results show that each technique is effective for a portion of the amphibian community and that the use of multiple techniques is essential to any assessment of these animals. They also show that amphibian activity is highly seasonal with early breeders, late breeders, and lots of variation due to weekly weather activity. Each of the isolated wetlands (e.g., limesinks, vernal pools) studied support a different suite of species despite the fact that wetlands are separated by as few as 40-50 meters. Even different portions of nearly homogeneous wetland habitat (e.g., pocosins) support different combinations of species. These results show that multiple techniques are needed for a full assessment of amphibian populations and communities at multiple sites and at the landscape level.

In addition to the research using standardized monitoring protocols, we marked 1,828 adult frogs for determination of movement distances and patterns of movement among isolated wetlands and between wetlands and terrestrial habitats. The total marked for the first two years of this project is now 2,377. In 2000, we recaptured 4 frogs on Dare Bombing Range, 8 on Cherry Point, and 6 on Camp Lejeune. Distances moved ranged from 30 to 360 meters. These preliminary results indicate that amphibians move considerable distances over the landscape. Such information is critical to formulation of effective ecosystem and landscape-level management plans because it supports the concept of management of habitats at broad scales.

A potentially serious amphibian disease was discovered Camp Lejeune in 2000. This disease has caused amphibian population declines in the western United States and species extinctions in the tropics. It does not harm humans and is thus a wildlife problem and a potential management issue. Frogs that are susceptible to this disease are prey for a large number of terrestrial and semi-aquatic predators, and tadpoles regulate energy dynamics of aquatic ecosystems. Because they are primary consumers and prey for a host of wetland species, loss of these ecologically important animals would have cascading effects and potentially alter natural ecosystem functions. At this time we should (1) continue monitoring and surveying amphibian populations on military installations in the East and Southeast, (2) determine if the disease is widespread, and (3) determine if the disease occurs elsewhere in the eastern United States. The work we will be doing in Year 3 of this project (FY 02 funding) will allow us to expand our survey on Camp Lejeune and to begin an initial survey of diseased amphibians on Fort Stewart, Georgia. Results of this work will be summarized in the final report for year 3.

I have not seen high levels of malformed amphibians on any of the three installations, although several individuals have been captured that had missing limbs. Incidence levels were well within natural background rates. Additional survey work is needed to determine if malformations may be occurring on other parts of these bases and on other installations.

The following general management recommendations apply to all three bases included in this project and may apply to other military installations in the region: (1) If the primary management goal for amphibians is to maintain current levels of species richness and viable population sizes, then a diversity of terrestrial and wetland habitats should be maintained. (2) Monitoring amphibian faunas is likely to reveal habitat distribution and population dynamic patterns that will be useful to resource managers. Because species presence or absent changes as habitats change and vary over time, monitoring of this fauna should be considered a long-term effort. Three years of research can provide the baseline data set for evaluation of future changes, however, monitoring should be done for many more years to detect trends. (3) Spraying herbicides and pesticides in and over terrestrial and wetland habitats could produce harmful results for amphibians, especially at the larval stage. Decisions to use chemicals in areas supporting amphibians should be made with extreme caution. (4) Natural hydroperiods of isolated wetlands should be maintained to the extent possible. Amphibians in areas with such wetlands have long been adapted to dramatic natural hydrological fluctuations. Activities such as ditching and clearcutting that result in increased evaporation should be avoided when and where possible.(5) The introduction of non-native and invasive species of plants and animals should be resisted. This could include North American “native” species found outside of these bases that could be harmful to amphibians. (6) Captive-raised or captive-bred amphibians (or reptiles) should not be released under any circumstances. The potential for disease introduction is growing and every effort should be made to avoid contamination from exotics or native species from other areas. Captivity often induces stress and influences development of disease. (7) It would be advisable to review existing management activities that affect the habitat and hydrology of target areas with management of amphibian communities and populations in mind. Such reviews may reveal conflicts that could be avoided or mediated if detected before problem arise. (8) It would also be advisable to review the myriad of wildlife management programs that are being used on military installations to identify procedures that may be in conflict with management activities that focus on amphibians.

INTRODUCTION

Management of natural resources on military lands by wildlife biologists and other habitat and land managers begins with the development of integrated natural resource management plans (INRMPS). Such plans set the stage for managing complex landscapes and biota by establishing specific criteria and goals. Among the goals included in most INRMPS are those that deal with maintenance of populations and communities of plants and animals, especially sensitive and listed species. Most ecologists and managers agree that one can be more effective in managing resources if one knows which species occur on his or her installation and how these organisms use the local landscape. The goals of today's INRMPS incorporate "ecosystem management" approaches, wherein the population and movement dynamics of all taxa are examined in light of the landscape context. Such an approach also incorporates information on aspects of land use by humans. This approach to management is a realistic way of increasing the probability that sensitive resources, such as amphibians, will remain viable for the long term.

This report is the second in a series of three projected reports that summarize results of a landscape-level project on populations and communities of amphibians (frogs and salamanders) in three U.S. military installations in eastern North Carolina. Amphibians were selected because they are well known to be sensitive to environmental change and perturbations (individuals exist as aquatic larvae and terrestrial adults), are declining and becoming rare in some areas (hence the need to determine status of all taxa), are well known taxonomically, and large quantitative data sets can be obtained with relatively low cost (Heyer et al., 1994). Conservation efforts on behalf of species with complex life cycles like amphibians require effective management of the full range of habitats used by aquatic larval, juvenile, and adult life history stages. Federal military installations provide excellent opportunities to develop methodologies that incorporate a landscape approach to management of such environmentally sensitive resources.

Most amphibian populations in the eastern United States exist as metapopulations in complexes of wetlands of various sizes and configurations located throughout the landscape (Semlitsch, 2000). Amphibians disperse among these wetlands at varying rates and travel substantial distances to do so. The varying hydroperiods (length of time pools hold water) in these wetlands create dramatic fluctuations in population sizes and reproductive success

(Pechmann et al., 1989, Rowe and Dunson, 1995; Semlitsch et al., 1996). Wetland types include Carolina bays, limesinks, and human-made surface depressions. Vernal pools include depressions in woodlands and managed grasslands, as well as road-side ditches and pools in unpaved roads created by vehicular traffic. Pools associated with roads are seldom permanent; yet support a wide diversity of amphibian species. My research on Fort A.P. Hill in Virginia (Mitchell, 1998b) and results of the work I have conducted so far (1999-2000) on the three installations in North Carolina indicate that seasonal wetlands allow amphibian communities to be more diverse and widespread than they would be without these bodies of water. Seasonal wetlands (e.g., limesinks, woodland pools, road ruts, miscellaneous surface depressions) provide critical habitat for reproduction, growth and development, and shelter. Wetland dynamics within the landscape play important roles in the dynamics of amphibian communities (Hecnar and M'Closkey, 1996). Because the variety of wetlands on the three installations in eastern North Carolina support different combinations of amphibian species and because these species exist as metapopulations on the landscape, it is imperative that we understand these dynamic systems so that we can develop management plans that work in these areas. Understanding the causes of the fluctuations is a critical precursor to creation of effective management recommendations (Semlitsch, 2000). In addition, the methodology used here can become a valuable tool for natural resource managers on military bases in the eastern United States

The few prior attempts at amphibian community assessment on military or wildlife refuge lands have been species-specific (e.g., listed species) or were incorporated into simple herpetofaunal inventories (e.g., Williamson and Moulis, 1979; Moler, 1985; Dodd and LeClaire, 1995), or they have not been conducted at all. A landscape approach within which a diversity of wetland types are evaluated is needed to better understand how amphibians use the natural resources on military installations. My project in eastern North Carolina allows us to evaluate amphibian communities and populations in several types of permanent and temporary wetlands. The overall goal is to understand the dynamics of these sensitive species and describe them in a way to allow identification of realistic management objectives. The success of the project in FY 00 (calendar year 2000, year 2 of the project) indicates that we are gaining realistic insights into the seasonal and habitat dynamics of the amphibians in the areas under study. Results from the third year will provide a more complete picture of amphibian dynamics at the landscape level and help to ensure that the management recommendations provided are realistic. This report summarizes the results of the fieldwork for FY 00. They are presented for each of the three military installations separately.

In addition to the monitoring components of this project, my field crew and I discovered a potentially serious amphibian disease on Camp Lejeune during the 2000 field season. This disease was confirmed by the National Wildlife Health Center run by the U.S. Fish and Wildlife Service. This information was taken seriously by the Legacy Resource Management Program staff and resulted in an additional commitment and an expanded research program for FY 01. In this report, I will summarize the findings by the pathologist at the center for 2000 and outline the fieldwork for the third year (2001 field season). This summary is located in the section on USMC Camp Lejeune.

PROJECT OBJECTIVES AND REVIEW FOR YEAR 1

1. To develop a landscape-level methodology for assessing the dynamics of amphibian populations in federal installations in the eastern United States. This approach will provide information critical to the management of these sensitive resources from an ecosystem perspective.

I used a variety of quantitative methods to assess amphibian communities and populations on the three military bases included in this project. The methodology and results were summarized in the report for FY 99 (Mitchell, 2000). A general result was that results were technique-specific. However, the use of multiple techniques in both aquatic and terrestrial habitats provided information on variation in relative abundance among sites and how these communities and populations changed over time (seasons) and how they differed among sites and habitats.

2. To provide the quantitative baseline against which future assessments of amphibian populations and communities on each installation can be evaluated.

The standardized techniques used in FY 99 resulted in a large quantified database on the dynamics of amphibian communities and populations on all three installations studied. These were summarized Mitchell (2000).

3. To provide installation personnel with the tools to monitor these sensitive organisms in the future so that population trends can be detected.

The specific tools include the continued use of the standardized quantitative techniques we used on the three installations. The training manual with specific instructions and information on identifying the amphibians designed for land managers on the installations is now in draft form. This manual will be revised during FY 01 to ensure that all the protocols are described adequately and the information on species identification is accurate and specific for these installations.

4. To provide realistic management recommendations to each installation that will allow resource managers to reach their goals of maintaining viable populations of each species.

I provided an initial set of management recommendations in the report for FY 99. Modified versions of these recommendations are included in this report, as well as others derived from insights gleaned during FY 00.

PROJECT OBJECTIVES AND REVIEW FOR YEAR 2

1. To continue the use of the standardized quantitative techniques developed during FY 99 during as many months as possible to gain additional insights into seasonal and landscape dynamics.

Standardized monitoring techniques in aquatic habitats were executed from February through October 2000. Standardized techniques in terrestrial habitats were executed from February through December 2000. Results summarized for each installation below constitute the baseline results derived from these techniques.

2. To obtain as much information as possible on the amphibians of the three installations so that the baseline dataset will be as robust as possible.

My field crew and I caught 9,560 individual amphibians during the course of the second year of this project. Of these, 2,819 were caught on Dare Bombing Range, 1,767 were caught on Cherry Point MCAS, and 4,984 were caught on Camp Lejeune. These large samples resulted in a large dataset that allow evaluations of the populations and communities in a variety of ways. These are summarized in this report.

3. To obtain the specific kind of information on techniques and species identification needed for the protocol manual and field guide that will be provided to installation land managers.

The information derived from the amphibians caught in year 2 of this project greatly aided in the descriptive information needed to develop the field guide that will accompany the final report for year 3. The standardized protocols were refined during the second year and will be described in detail in the protocol manual and field guide supplement.

4. To obtain additional insights into the amphibian communities and populations on the three installations so that the management recommendations provided will be as realistic and effective as possible.

The information derived from the standardized monitoring protocols, summarized in this report, provided insights into the relative abundances of most populations of amphibians encountered on the three military installations included in this study. The protocols used also allowed descriptions of the communities of amphibians in each habitat studied. These are summarized in the tables included in this report.

5. To obtain as much information on as many aspects of the biology of these sensitive animals as possible so that any potential problems with the target populations may be revealed.

This objective is usually an unstated goal of all my projects. Generally, the task is to obtain as much information as possible about all aspects of the animals under study so that we can detect any potential problems that may influence their viability in a study area. In recent years, the concerns over developmental malformations and disease have heightened our awareness to be ever-vigilant. This attention to all aspects of the biology of amphibians during the course of this study resulted in the unexpected discovery of a potential disease problem on one of the installations. This disease is described below in the section for Camp Lejeune.

PROJECT OBJECTIVES FOR YEAR 3

1. To obtain a third year of baseline data on the populations and communities of amphibians on the three military installations in eastern North Carolina.

2. To complete the evaluation of annual and seasonal dynamics of populations and communities on the three installations so that wildlife biologists and land managers have a better understanding of these species under their care.

3. To obtain as much information as possible on amphibian movement distances between aquatic breeding sites and between breeding sites and terrestrial non-breeding sites so that realistic recommendations can be made regarding management at the landscape level.

4. To provide effective and realistic management recommendations that can be used by wildlife biologists and land managers in the Southeast to ensure the long-term viability of amphibians on their installations.

5. To complete the protocol manual and field guide supplement on the amphibians of eastern North Carolina so that wildlife biologists and land managers will have the tools to continue long-term monitoring of these animals.

6. To demonstrate to installation wildlife biologists and land managers the standardized protocols used for monitoring and the basic field identification of the amphibians on their installations.

7. To provide a summary of the amphibian health survey and potential disease problems conducted on two installations in the Southeast (Fort Stewart and Camp Lejeune) in FY 01.

8. To provide recommendations to the installations and the Department of Defense on future projects and courses of action that will enhance our understanding and control of amphibian diseases on military bases in the Southeast.

GENERAL METHODS

In 1999 I selected three military installations in the Southeast for a monitoring project on amphibian populations and communities at the landscape level: Cherry Point Marine Corps Air Station, Camp Lejeune (USMC), Dare County Bombing Range (USAF), all located in eastern North Carolina (**Figure 1**). Cherry Point MCAS is located in Craven County, NC, Camp Lejeune is in Onslow County, NC, and Dare County Bombing Range is in Dare County, NC.

Standardized methods used to monitor amphibians on all three installations in FY 00 (year 2 of the project) included (1) weekly nighttime assessments of vocalizing frogs during the breeding seasons executed from February through September (<u>frog call surveys</u>), (2) monthly daytime assessments of the composition of larval communities using <u>dipnet surveys</u> and <u>minnow trap surveys</u> conducted February-October, (3) terrestrial transects using plywood and roofing tin <u>coverboards</u> and refugia made of <u>PVC pipe</u> executed February-December, and (4) <u>visual encounter surveys</u> conducted during transect searches and during nights when work was being conducted in the installation. In addition, all frogs in the genera *Bufo* (toads), *Hyla* (treefrogs), *Pseudacris* (chorus frogs), and *Rana* (true, or ranid, frogs) that we captured were permanently marked with a site number by surgically removing 1-2 toes. Recaptures of marked frogs in years 2 and 3 will provide assessments of movements between wetland and upland habitats and among wetlands on the landscape.

<u>Site Selection</u>: All study sites on the three military bases (Cherry Point Marine Corps Air Station, Camp Lejeune (USMC), Dare County Bombing Range (USAF)) were selected by the end of April 1999. Several isolated wetland sites on Cherry Point MCAS (11) and Camp Lejeune (18) were targeted for evaluation of seasonal changes in amphibian community structure. In addition, my field crew and I established six coverboard and PCV pipe transects in the surrounding forest at each of these two installations. At Dare County Bombing Range, we selected three forest types for study using the coverboard transect technique: hardwood forest, mixed hardwood and pine forest, and Atlantic white cedar forest. Dare County Bombing Range has none of the small ponds and pools that characterize the other two bases; the ecosystem is entirely pocosin with a very wet substrate. Pools of water form temporarily in surface depressions in the forest and there is a

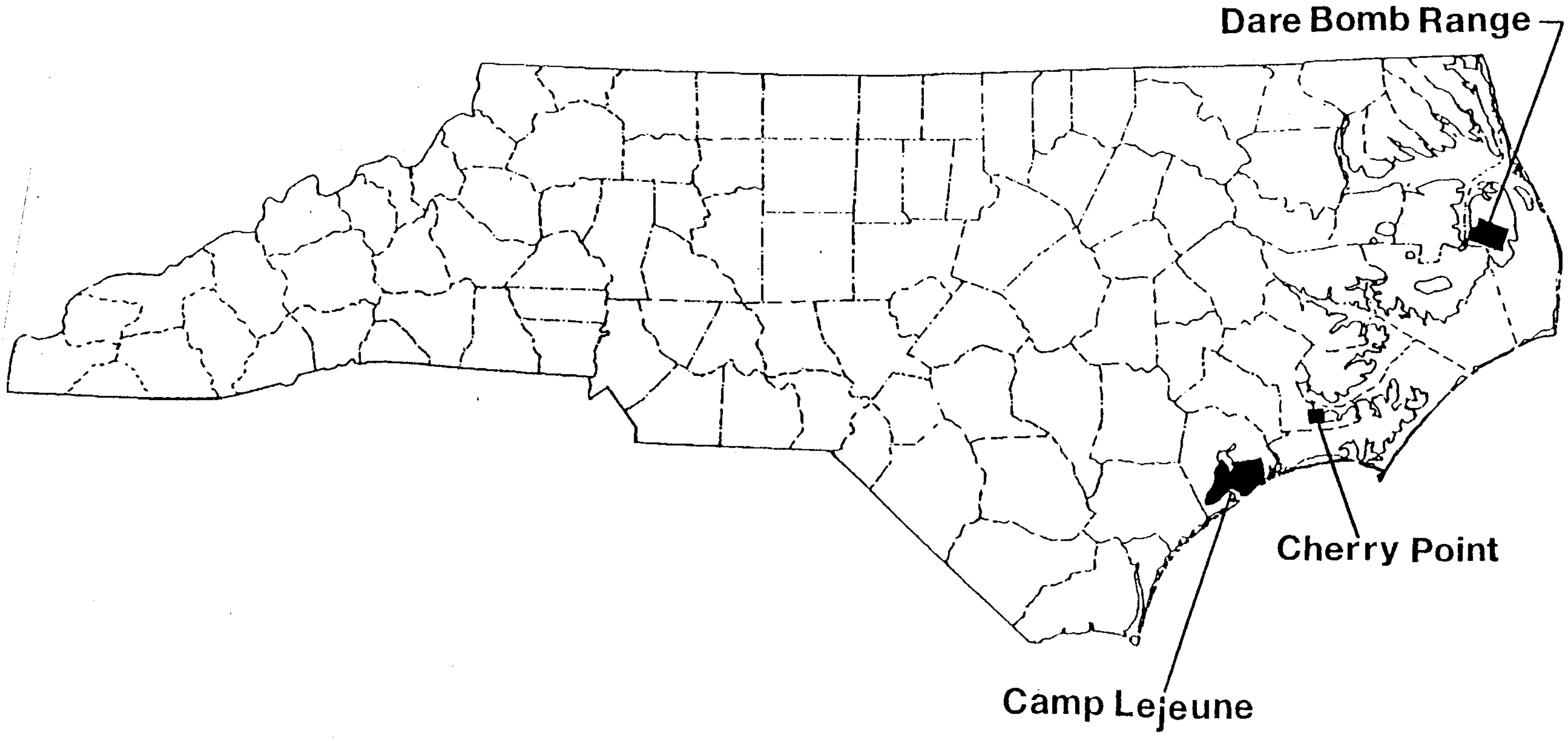

Figure 1. Map of North Carolina illustrating the geographic locations of the three military installations on which the amphibian monitoring study was conducted.

matrix of roads and drainage ditches that remain wet year round. These two different aquatic habitats allowed us to assess the amphibian communities in this location.

Amphibian Monitoring Methods: My field crew and I used several standardized methodologies (protocols) in the course of this project that provide information on the amphibians in each of the study areas on each of the installations.

(1) Frog call surveys - Species-specific frog vocalizations were taped and assessed by ear on one night each week at 7-8 primary study sites (isolated wetlands) during the calling season. All data are recorded on standardized field data forms (see Appendix 2 in Mitchell, 2000). This method was initiated in February 2000 and continued until frogs ceased calling in September. Calls were taped for a standardized 5 minutes, following the protocol used by the North American Amphibian Monitoring Protocol (USGS-BRD, Patuxent Wildlife Research Center, http://www.pwrc.usgs.gov).

(2) Aquatic larval and adult surveys - Aquatic larval (tadpole and salamander larvae) and adult amphibian communities were evaluated on a monthly basis February through October 2000 in the selected isolated wetlands on each installation. We use two methods to quantify numbers of tadpoles and salamanders caught: minnow trap surveys and dipnets surveys (see Appendix 1 in Mitchell [2000] for examples of the field data forms). Ten to 50 minnow traps (number depends on size of pool) were set in isolated wetlands on one day and checked the next. Traps were set so that air-breathing animals caught (e.g., adult frogs, snakes, turtles) would not drown. All amphibians and their larvae captured were identified and counted. Animals caught in standardized (1 meter) sweeps of aquatic dip nets (number of sweeps were comparable to the number of minnow traps per pool) were also identified and counted. These two methods provided quantitative comparisons between these two methodologies and allowed comparisons among isolated wetland sites and across time.

(3) Coverboard and PVC refugia transects - Terrestrial coverboard transects were installed in all sites in May and June 1999; six each on Cherry Point and Lejeune and nine in Dare Bombing Range. Coverboards were made from 2x4 foot sections of plywood and sheets of roofing tin.

They were positioned 10 meters apart along a 300 meter transect. There are 20 boards and 10 sheets of tin per transect. Thus, each transect has 30 coverboards; 180 each for Cherry Point and Camp Lejeune and 270 in Dare Bombing Range (630 total). In addition, ten 1.5 meter sections of 1.5 inch PCV pile were installed upright at each of the tin sites on each transect. Thus, each 300 meter transect consists of 20 plywood coverboards, 10 sheets of tin, and 10 sections of PCV pipe. These transects were checked monthly February through December 2000. Examples of the field data sheets are in Appendix 1 in Mitchell (2000).

(4) Visual encounter surveys - An effective way to obtain information on the presence or absence of amphibians is to walk through the habitat and search for active and conspicuous individuals and those in all possible hiding places (e.g., under surface cover objects). This approach is sometimes called the haphazard method of searching. It is largely an inventory technique rather than a monitoring because it is difficult to quantify the results. The visual encounter survey method was used in this project in conjunction with the other, more quantifiable, methods. The results presented for each base for this method reflects the numbers of individuals of each species observed and captured that were not specifically taken with the other methods. In short, these data represent the amphibians observed haphazardly or during night searches to obtain animals for marking.

(5) Marking frogs - All frogs caught at terrestrial transects and many of them caught at isolated wetland sites were identified, measured, and marked with a unique site number. Marking was done by surgically removing 1-2 toes from each frog with cuticle scissors. No more than two toes were removed from each individual and we never removed thumbs as males use them during mating to hold on to the female (= amplexus). Toes were preserved and saved by placing them in small vials with ethanol for later studies on skeletochronology (age) and genetics by colleagues. Toe numbers refer to isolated wetland number and terrestrial transect number. Upon recapture of marked frogs, comparisons of original and recapture locations provided information on how far these animals moved from the isolated wetland or terrestrial non-breeding location and whether they used more than one of the isolated wetlands for breeding.

Terrestrial Habitat Analysis: We conducted plant ecology analyses of each of the coverboard transects in July and August 1999. Detailed habitat descriptions, plant species names, and their relative abundances in the three installations are in Mitchell (2000).

Field Crew: The field crew was largely based out of East Carolina University in Greenville, NC. One crew leader has his Master's Degree and another is in the process of completing his. Both teach at the college level. The third crew leader has his BS degree and has shown leadership skills during previous years. Most support-level members of the crew (= field technicians) were undergraduates at East Carolina University. Most of the others were knowledgeable amateur herpetologists in eastern NC. All of the field crew personnel have conducted numerous field trips and have assisted in all phases of the work. In general, the field crews have performed well and have ensured that the data obtained are accurate. Most of the funding for this project paid for the time all members of the team spent in the field on the three installations.

Interactions with installation resource personnel: All of the Points-of-Contact at each of the military installations have been very helpful throughout the project. They have encouraged us to continue this project for several more years. They have been instrumental in helping with site selection and continued access. Base military police and range control personnel have been very helpful in allowing us access to all our study sites when we needed to be there.

Data computerization: Field observation data were written initially on field data sheets and subsequently entered into computerized Excel spreadsheets for evaluation and summary. These data are summarized below for each installation by protocol type. An electronic copy of the baseline data will be given to the Points-of-Contact at each installation.

Schedule: All aspects of the fieldwork began in February 2000 and were conducted through September 2000. This period included contacts with appropriate base personnel, re-evaluation of access constraints and securing base contractor passes, monthly monitoring of coverboard transects, execution of weekly frog call surveys, monthly assessment of amphibian larval communities in isolated wetlands using dipnet and minnow trap survey protocols, capture of numerous frogs and salamanders for marking, the recapture of several frogs that have had been marked previously for determination of distances moved, and management of field personnel.

Terrestrial coverboard transect surveys were run monthly through December. Aquatic dipnet and minnow trap surveys in isolated wetlands were run monthly through October. Weekly frog call surveys were run from mid-February until the frogs ceased calling in September. Capture and marking of frogs were integrated throughout the year and done largely at night during visual encounter surveys.

Titles of Papers Presented during FY 00:

Mitchell, J.C. 2000 Monitoring amphibians on military bases in the mid-Atlantic. NMFWA, Chicago, IL. 26 March.

Mitchell, J.C. 2000. Snake education: A pilot project on Camp Lejeune. NMFWA. Chicago, IL. 26 March.

Mitchell, J.C. 2000. Monitoring amphibians on military bases. Northeastern Partners in Amphibian and Reptile Conservation (PARC) meeting. Patuxent Wildlife Reararch Center, Laurel, MD. 13-15 October.

Mitchell, J.C. 2000. Monitoring anuran communities on military bases in the mid-Atlantic: variation among sites and techniques. Joint meeting of the American Society of Ichythologists and Herpetologists, The Herpetologists' League, and the Society for the Study of Amphibians and Reptiles. La Paz, Baja California Sur. 14-20 June 2000.

RESULTS FOR DARE COUNTY BOMBING RANGE (USAF)

INTRODUCTION

The Dare County Bombing Range is located in Dare County, North Carolina, approximately 19 kilometers south-southwest of the town of Manns Harbor. Alligator River National Wildlife Refuge essentially surrounds Dare Bombing Range. The Range consists of 46,600 acres, of which the majority (approximately 80%) is managed for silvicultural activities and wildlife management, hunting, fishing, and other outdoor activities. The acreage is leased to the North Carolina Wildlife Resources Commission who manages the hunting programs. The remaining acreage occurs in two separate parcels and is used by the Air Force and Navy for pilot training. Habitats on Dare County Bombing Range consist of a diversity of wetland types, most of it characterized as pocosin, Atlantic white cedar forest, and various wet hardwood and mixed forest communities. Numerous roads, flanked by drainage canals, crisscross the property. These canals (ditches) served originally to lower water levels in the forest so that logging could take place. Timber management and logging operations continue on military lands, and the area is now a patchwork of forests of mixed community types. Atlantic white cedar was the dominant canopy tree but years of logging with little attention to management left patches of mixed hardwoods, pine, and cedar trees. The pocosin habitat is a wet habitat and in many places the substrate is soft and peaty with water at or underneath the surface. Amphibians occupy all of the terrestrial habitats, as well as all aquatic systems in the area.

The extensive nature of the altered pocosin habitat and the lack of ephemeral pools and ponds in the area created a challenge to using standardized amphibian monitoring techniques that proved effective in other habitats that have pools and ponds (see results for Cherry Point MCAS and Camp Lejeune). My field crew and I were able to monitor the amphibians the Dare Bombing Range study area all of the standardized techniques, although some techniques worked better than others. Most of the individuals we marked for evaluations of distances moved were obtained during visual encounter surveys.

Amphibian species richness expected for Dare County Bombing Range is based on species distribution maps in Conant and Collins (1998) and include 17 species of frogs and toads and 7 species salamanders. In 1999, we caught or observed 14 species of frogs (82% of expected) and 4 species of salamanders (57% of expected). In 2000, we caught or observed the same 14 species of frogs (82%) but only two species of salamanders (29%).

Amphibian monitoring was carried out primarily at several wetland and terrestrial forest study sites in an area bordered chiefly by H & B and Smith roads on the west side, by Beechland Road on the east side, and Navy Lead Road to the north (**Figure 2**). This report summarizes results from the fieldwork conducted in this area during FY 00 (the February -December 2000 amphibian field season).

STUDY SITE DESCRIPTIONS

General Habitat Description

The dominant habitat type in mainland Dare County, North Carolina, is pocosin. Total wetland area in the county is 86,367 ha, whereas non-wetland area is comprised of 14,983 ha (101,350 ha total land area) (Moorehead, 1999). Pocosin habitat in the Atlantic Coastal Plain is characterized by non-alluvial hydrology (fed by rainwater or groundwater), acidic soils (peat or wet mineral), and a dense, generally evergreen, shrub layer (Weakley and Schafale, 1991; Sharitz and Gresham, 1998). Pocosins were classified by the Cowardin et al. (1979) system as palustrine wetland ecosystems. This ecosystem is typified by long hydroperiods, temporary surface water, soils of sandy, humus, peat, or muck, and periodic fires (Sharitz and Gresham, 1998). In the Dare County Bombing Range study area, standing water occurred mostly in the human-dug channels along access roads, but often as puddles in “terrestrial” forested habitats. The channels were deep and all had extensive woody vegetation that lined the side of the channel closest to the dirt road.

Precipitation Summary for 2000

Precipitation levels for 2000 exceeded those recorded for 1999. For five months of 2000 (February, March, May, October, December), Dare County received less than normal precipitation (**Figure 3**). Above average precipitation occurred in the months of January, April, June through September, and November. In 1999, total rainfall was higher than normal only for June and August – October when rainfall occurred mostly from two hurricanes (Floyd and Dennis) (Mitchell, 2000).

Terrestrial Habitat Descriptions

Results of the vegetative analyses for the three primary forested study sites on Dare County Bombing Range were summarized in Mitchell (2000). Abbreviated descriptions for each study site follow below.

Site 1 (Mixed hardwoods) - This site lies to the north of Pine Road at its juncture with Beechland Road. The site consists of a wet mixed hardwood forest dominated by red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), and sweetgum (*Liquidambar styraciflua*). The forest floor at this site features numerous shallow depressions which fill with water during wet periods. Coverboard transects 1900, 2000, and 2100 were located in this site.

Site 2 (Mature Atlantic white cedar) - This site lies along Sycamore Road approximately 1.2 km south of the junction of Navy Lead Road. The overstory is dominated by Atlantic white cedar (*Chamaecyparis thyoides*), tupelo gum (*Nyssa aquatica*), and red maple (*Acer rubrum*). This site is the wettest of the three study areas in which artificial coverboard transects were established. Coverboard transects 1300, 1400, and 1500 were located in this site.

Site 3 (Mixed pine-hardwoods) - This site lies to the west of Beechland Road just north of the junction of Holly Road. The dominant overstory trees are sweetgum (*Liquidambar styraciflua*) and loblolly pine (*Pinus taeda*). Understory trees are dominated by red maple (*Acer rubrum*), sweetgum, and sweetbay (*Magnolia virginiana*). Coverboard transects 1600, 1700, and 1800 were located in this site.

Control site (Site 4, Atlantic white cedar control area) - This site lies along Richmond road just east of the junction of H & B road. The site features a young stand of Atlantic white cedar (*Chamaecyparis thyoides*) regenerating on a former clear-cut. The majority of these trees are 2-3 meters in height. Some red maple (*Acer rubrum*) is present and the fringes of the site, as well as some areas within the site, support an understory of wax myrtle (*Myrica cerifera*). A thick mat of moss (*Sphagnum* sp.) covers the ground over much of the site. This site served as a "control" area for comparison to results from the herbicide spray site (Site 5). Minnow traps were used extensively in this site due to the amount of standing water.

Spray Site (Site 5, Atlantic white cedar spray area) - This site lies at the junction of Smith and H & B roads near the western edge of the Dare Bombing Range. As with site 4, above, this site features a stand of young Atlantic white cedar of approximately the same age and height. Subcanopy and ground vegetation characteristics are similar to those in site 4. However, this site is currently being actively managed to enhance the growth of Atlantic white cedar. Part of the management program involves the use of herbicides to control broadleaf vegetation, thus reducing competition stress for Atlantic white cedar. Herbicides (Arsenal™) were applied at this site in late November 1999. Minnow traps were used extensively in this site because of the extensive standing water most of the year.

Shallow Aquatic Habitat Descriptions

Twenty other small aquatic sites in the study area on Dare County Bombing Range were trapped intensively with minnow traps in 2000. These sites are represented by letters on Figure 2. Each is described briefly below. All were shallow pools or wet areas deep enough to allow minnow traps to be set so that part of the trap was above the water line. The aquatic environment in pocosin habitat in this area is generally acidic, as pH readings ranged from 3.96 to 6.06 in nine sites sampled (**Table 1)**. All of the dirt roads in our study area were bush-hogged during 2000. Consequently the vegetation descriptions given here apply primarily to the banks of adjacent canals and ditches across from the roads. The banks of the roads generally lack vegetation. Descriptions of lettered sites include a stretch of road plus adjacent ditches and/or canals.

Site Descriptions (Sites A-H, J-K, M, P-T) -

Site A: Pine Road and adjacent ditch and canal. The ditch on the north side is shallow and its bank supports much emergent vegetation (i.e., cane [*Arundinaria sp.*] and *Juncus* sp.). The Ditch dried up twice in 1999 and once in 2000. The canal on the south side is bordered by mixed hardwoods.

Sites B and C: Stretches of Beechland Road bordered by canals on either side. East side canals are slightly deeper and wider than those on W. side.

Sites D, E and F: Stretches of Navy Lead Road between Dry Ridge South Road and Beechland Road. Canals on both sides are identical, mostly bordered by clearcuts and second-growth forest.

Sites G, H and J: Stretches of Holly road between Navy Lead Road and a point where Holly Road makes a right-angle turn eastward to its junction with Beechland Road. They are bordered by shallow ditches on the west side. Ditch at site “J” was dry much of 1999 and for part of 2000. Vegetation in these ditches consists of *Juncus* sp., red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and cane (*Arundinaria* sp.). The canals on the east side are deep, wide, bordered by much the same vegetation, albeit older growth.

Site K: Stretch of Holly Road running due west of Beechland. The description for this site is identical to that for site “A” (above), except that a portion along its north side was clearcut in 2000.

Site M: Stretch of Sycamore Road below Navy Lead Road. The canal on the east side is deep and there are shallow ditches/depressions on west side. Adjacent habitat is mostly comprised of clearcuts and second growth. West side ditches have dried up several times.

Site “N” lies just below site “M” along Sycamore Road but has never had enough water to sample.

Site P: Stretch of Sycamore Road adjacent to Atlantic white cedar stand. There is a shallow ditch on the west side with Atlantic white cedar, red maple, and some young cypress on the bank. The canal on the east side is deep.

Site Q: East-west running stretch of Sycamore Road. There is a deep canal on the south side. A recent clearcut occurs on the north side. The area is often flooded (most likely because of construction of the road embankment). Clearcut areas occur on the south side across the canal as well.

Sites R and S: Stretches of Dry Ridge South Road above and below the junction with Richmond Road. Deep canals lie on either side. Woods along each consist mostly of mixed forest (some pine, including loblolly and pond pine [*Pinus serotina*] and various hardwoods).

Site T: Stretch of Richmond Road west of Dry Ridge South Road. There is a deep canal on the North side and shallow ditches/ depressions occur on the south side. Habitat on both north and south sides is regenerating Atlantic white cedar, whereas that on the north side is older. The area is very wet. Ferns (*Woodwardia* sp.), mosses (*Sphagnum* sp.), red maple, and red bay (*Persia borbonia*) occur at this site.

METHODS SPECIFIC TO DARE COUNTY BOMBING RANGE

The pocosin habitat in mainland Dare County, North Carolina, created a special challenge for using standardized monitoring methods for amphibians. Our initial efforts to trap and dip in the deep ditches that parallel most of the roads in this habitat proved unsuccessful. Shallow pools in the forested pocosin could be trapped with minnow traps and we conducted numerous trapping events when there was water on the surface. This included shallow areas in the edges of forested and recently altered habitat. The lack of ephemeral (vernal) pools and the deep channels meant that we could not use the dipnet survey approach. We had to devise alternative methods that worked in this unique habitat type. In the 2000 field season we used Visual Encounter Surveys during wet periods at night to capture frogs crossing roads.

RESULTS

A total of 14 species of frogs and toads, four species of salamanders, 7 species of turtles, 5 species of lizards, and 17 species of snakes have been observed during the first two years of fieldwork in the Dare County Bombing Range area (**Table 2**). During 2000, we encountered all 14 species of frogs but only two species of salamanders during our work on amphibians in the study area (**Table 3**). Total number of individuals of these species captured as larvae, juveniles, adult males, and adult females was 2,819, a nearly five-fold increase over the number captured in 1999 (Mitchell, 2000). Tadpoles of a very common frog, *Rana clamitans* (northern green frog) comprised 27% of all amphibian captures. Captures of all life history stages of this frog comprised 50% of all frog captures. Captures of 2 to 957 individuals of the remaining frog species of frogs and 23 to 60 captures of the two salamander species represented our capture success in 2000. Frogs in the genus *Rana* dominated the frog fauna on Dare County Bombing Range. We now believe that we have determined the relative abundance rankings of most of the frogs in the area.

Frogs and salamanders were captured during the execution of the six standardized monitoring protocols (**Table 4**). Dipnet surveys were successful in capturing five species of amphibians in the pocosin habitat in 2000. Results of each technique used provided a different suite of species. Note that three techniques yielded the most species, visual encounter surveys, minnow trapping, and frog call surveys. The nighttime frog call survey was the only method we used that encountered all species of frogs. Salamanders were encountered only by the coverboard technique, during visual encounter surveys, and with minnow traps.

Artificial coverboards transects were moderately successful in capturing amphibians at Dare County Bombing Range in 2000 (**Table 5**). A total of four frog species and one salamander species was found under coverboards. The largest number of frog captures was of juvenile green frogs (59). A total of 43 terrestrial plethodontid salamanders (Atlantic Coast Slimy Salamander, *P. chlorobryonis*) were found under cover. Single individuals of three frogs were encountered with this method. Most of the individual captures were in the mixed forest (54%), whereas 36% of the captures occurred in the hardwood forest and 9% were in the Atlantic white cedar stand.

Frogs occasionally use the cavities provided by the upright and isolated PVC pipes for refugia (see results for Cherry Point MCAS and MCB Camp Lejeune). During 2000, four species of treefrogs were found in the 90 pipes at the Dare County Bombing Range study site (**Table 6**). Gray treefrogs (*Hyla chrysoscelis*) was the most commonly encountered species, followed by the pine woods treefrog (*Hyla femoralis*). One and two captures of squirrel treefrogs (*Hyla squirella*) and green treefrogs (*Hyla cinerea*), respectively, were captured in PVC pipes. Most captures (77%) occurred in the mixed hardwoods and pine stand. Number of captures in 2000 greatly exceeding the single capture in 1999, not doubt due to the greater amount of rainfall in the second year.

Most amphibians encountered at Dare were observed or caught during the execution of trapping techniques (minnow traps), visual encounter surveys, or during frog call surveys. A total of 917 individuals of nine species of frogs and two individuals of one salamander species was observed during visual encounter surveys (**Table 7**). Two species were captured in abundance with this method, green frogs (*Rana clamitans*) and southern leopard frogs (*Rana sphenocephala*). Single individuals of two species of frogs were encountered, whereas numbers of individuals for five other frogs ranged from 3 to 99. This method proved to be many times more successful in 2000 than in 1999.

Minnow trapping yielded the most captures and the highest capture success of all methods used at Dare County Bombing Range in 1999 (Mitchell, 2000) and in 2000 (**Table 8**). The use of this technique in pools in the nine terrestrial transects when they had surface water deep enough to set traps yielded 1-82 captures per transect. Trapping in the spray and "control" sites yielded the most captures, 188 and 371, respectively. Trapping in a variety of other shallow sites in the area yielded 1 to 201 captures. Tadpoles of the three species of *Rana* (*R. clamitans, R. sphenocephala, R. virgatipes*) comprised 97% of all captures with this method. Only 12 individuals of the bullfrog (*R. catesbeiana*) were captured in 2000. The treefrogs *Hyla chrysoscelis* and *Hyla femoralis* were captured in low numbers but this is likely attributed to their arboreal habits and not true relative abundance. Only one salamander, the completely aquatic amphiuma (*A. means*) was captured by the minnow trap technique. Capture success in pools along the terrestrial coverboard transects in the three forest types was 0.866 individuals per trap night. Success in the spray and control areas was considerably higher at 1.49 individuals per trap night. Capture success in other sites mirrored the forest sites with 0.832 individuals per trap night. Thus, the minnow trap technique has proven to be a highly successful technique in pocosin habitat.

Relative abundance of amphibians and predatory invertebrates in Atlantic white cedar forest sites varied between predator and prey species, among amphibian species, and across months (**Tables 9-11**). Relative abundances of predatory crayfish (*Procambarus acutus*) and predaceous diving beetles (*Cybister frimbriolatus*) were as high or higher than that for tadpoles and generally corresponded with tadpole abundance on a seasonal basis. Relative abundance of amphibians varied from no captures to as many as 52 captures per 50 trap nights. Relative abundance of crayfish varied from zero to 215 captures per 50 trap nights. The highest numbers of crayfish occurred at a time (May-June and October) when amphibians were present in relatively large numbers. Predaceous diving beetles were present primarily during May and June, adding to the predator pressure on tadpoles in this habitat. Such aquatic predators undoubtedly have dramatic impacts on the amphibian assemblages in these aquatic habitats.

Number of captures of amphibians in dipnet sweeps were low and attributable to the difficulty of using this technique in pocosin habitat. A total of 41 individuals of five species of frogs were captured (**Table 12**). Capture success was 0.216 individuals per sweep of the dipnet.

Frog call surveys in Dare County Bombing Range were conducted weekly from 27 February through 27 August 2000. A total of 14 species was encountered with this technique (**Table 13**), corresponding to all known frog species expected for this area. Number of species recorded per site ranged from 6 (site 2) to 12 (site 9) (see **Figure 3** for site locations). Number of sites occupied by each frog species ranged from one for the little grass frog (*P. ocularis*) to all nine sites for four species (southern cricket frog [*A. gryllus*], Cope's gray treefrog [*H. chrysoscelis*], green frog [*R. clamitans*], and carpenter frog [*R. virgatipes*]).

Weekly variation in individual species calling during site visits and variation among sites was dramatic (**Tables 14-22**). The length of time a particular species called at a given site during the 2000 study varied from calling many weeks in succession (9 of 9 sites for the southern cricket frog [*A. gryllus*] and carpenter frog [*R. virgatipes*]) to only once in the entire study season (1-3 species per site). These species were usually southern toads (*B. terrestris*), narrow-mouthed toads (*G. carolinensis*), and green treefrogs (*H. cinerea*). Based on calling males, the frog fauna at Dare County Bombing Range was dominated in 2000 by southern cricket frogs (*Acris gryllus*), followed by green frogs (*Rana clamitans*), carpenter frogs (*Rana virgatipes*), southern leopard frogs (*R. sphenocephala*), pinewoods treefrogs (*Hyla femoralis*), green treefrogs (*Hyla cinerea*), and Cope’s gray treefrog (*Hyla chrysoscelis*). The bullfrog (*Rana catesbeiana*), a predator of other frogs, was prominent at only two of the sites in 2000, compared to half of the sites surveyed in 1999. Other species called only sporadically in these sites in 2000.

We marked a total of 1,056 individual frogs in 2000, a 26-fold increase from the 41 marked in 1999 (**Table 23**). Most of these were marked during visual encounter surveys. The following species were marked: southern toads (*Bufo terrestris*), Cope's gray treefrog (*Hyla chrysoscelis*), green treefrog (*Hyla cinerea*), pinewoods treefrogs (*Hyla femoralis*), squirrel treefrogs (*Hyla squirella*), bullfrogs (*Rana catesbeiana*), green frogs (*Rana clamitans*), southern leopard frogs (*Rana sphenocephala*), and carpenter frogs (*Rana virgatipes*).

Four frogs previously marked that moved locations since their original capture were caught in 2000, one green frog (*R. clamitans*), one pine woods treefrog (*H. femoralis*), and two southern leopard frogs (*R. sphenocephala*) (**Table 24**). Minimal distances moved were 150 meters for the green frog, 100 meters for the treefrog, and 160-380 meters for the leopard frog. These preliminary movement data suggest that at least several species of frogs move considerable distances in pocosin habitat.

DISCUSSION AND CONCLUSIONS

Capturing amphibians on Dare County Bombing Range was initially more problematic than anticipated. The difficulty was entirely due to the nature of the habitat type (pocosin) characteristic of the region and the fact that there were few sites where these animals concentrated (e.g., isolated wetlands used for breeding). Amphibians in pocosins apparently breed throughout the extensive wetlands. We were able to capture fewer than 600 amphibians in 1999 with a series of standardized monitoring techniques. However, in 2000 we determined that visual encounter surveys conducted at night greatly aided our sampling effort and supplemented standardized techniques. This addition to the list of techniques used, as well as the fact that we worked in this installation over a longer period of time than we could in 1999, resulted in a five-fold increase in the number of amphibians captured in 2000. The result is that we are confident that the list of frog species that occur on Dare County Bombing Range is complete. We are less sure of the species list for salamanders, as most of them are more difficult to encounter than frogs in pocosin habitats.

The results obtained from studies such as this one depend entirely on the techniques used to capture and encounter the target species. Amphibians are especially vulnerable to the biases inherent in standardized monitoring protocols. The results presented in the tables demonstrate well that one obtains different lists of species and different numbers of individuals with each technique. Add to this the great variation in relative abundances of the life history stages and seasonal variation in activity characteristic of amphibians and one can easily see that obtaining a true picture of the dynamics of amphibian populations and communities is very difficult. The best approach, in my opinion, is to use a variety of techniques to survey and monitor amphibians in a target area. The repeated use of multiple standardized techniques helps to ensure that the baseline database is robust and can be compared to such data taken at different times in the future. Long-term use of these combined techniques will provide the best picture of the status of the amphibian community on Dare County Bombing Range.

A primary conclusion on the status of the amphibian community based on two years of research at Dare County Bombing Range is that it is a seasonally dynamic but healthy assemblage of species representative of pocosin habitats in the lower mid-Atlantic region. This is based on the similar numbers of species obtained in the first two years of this study, comparison of lists of expected and actual species, and the large numbers of individuals present in this pocosin habitat. Two aspects of the amphibian community in this installation that may be addressed in the third year of this study, in addition to adding another layer of baseline data, are (1) more detailed information on the movement distances of as many species as possible, and (2) additional information on species-specific associations by habitat and microhabitat.

The results we obtained in the second year of this study on movement distances traveled by frogs in pocosin habitats are suggestive of considerable dispersal in the landscape. We obtained only four records of movement from one site to another in 2000. However, the distances traveled by these four small vertebrates varied from 100 to several hundred meters. Additional captures of marked individuals in the 2001 field season should yield considerable additional information on movements. These observations will provide insights into how these animals use the landscape in this installation. At this point we can hypothesize that many species move long distances and do not restrict their movements to specific patches of habitat. Such a hypothesis would be in concert with information on frogs that are well known to disperse long distances in other areas and habitats (see reviews in Semlitsch, 1998; Pauley et al., 2000).

Frogs and salamanders in Dare County Bombing Range use a variety of habitats. We have observed frogs in areas with open and closed canopies, in pools along the edges of the dirt roads, in pools in recently logged sites, and in pools throughout various forest types. Salamanders appear to be more habitat restricted, with several being found only in forests and at least one (the Amphiuma) occupying the ditches and pools along forest and road edges. These observations suggest that frogs at least are less restricted to specific habitats than salamanders. Evaluation of specific habitat types used by each species in the report for year 3 will reveal additional insights into how these vertebrates use the landscape dominated largely by pocosin habitat.

Aquatic amphibians, especially larval communities, are regulated by a variety of factors, including their own densities and those of predators. Our preliminary data on relative abundances of tadpoles and two species of invertebrate predators in the Atlantic white cedar stand suggests that such predators may play important roles in the dynamics of tadpole communities and populations in forested pocosin habitats. Understanding their dynamics, perhaps derived from future studies, will help us understand the roles of predators and prey in pocosin habitats.

Formulation of realistic management objectives for amphibians will require the results of all three years of data derived from this study. The following conclusions and management recommendations are based on two years of study on Dare County Bombing Range and should be considered preliminary and accepted with a degree of caution.

1. The pocosin habitat characteristic of Dare County Bombing Range supports a rich diversity of amphibians dominated by a robust frog fauna and a small community of salamanders. No rare or listed species have been found.

2. Use of multiple standardized monitoring and capture techniques is required to encounter the entire amphibian fauna. No one technique is useful to monitor all life history stages of all species. Multiple techniques are necessary for long-term monitoring and comparisons with the database being developed in this study.

3. The nighttime frog call survey is the best technique to assess the presence or absence of a frog species at a particular site, although it can say little about its reproductive use or success in a specific habitat or site.

4. Determination of whether a particular site is used for reproduction requires the use of at least the minnow trap technique.

5. Effective monitoring of amphibians in expansive pocosin habitats typical of the Dare County Bombing Range requires the creative use of the visual encounter survey technique in addition to the suite of standardized monitoring techniques.

6. The amphibian fauna at Dare County Bombing Range is seasonally dynamic and its composition varies dramatically over relatively short distances in the landscape. Monitoring of all species requires multiple techniques used over the entire season, including winter, to obtain information on all species present.

7. Preliminary information on distances moved by frogs in pocosin habitat suggests that movements are not limited and can occur across large areas. This suggests that frogs at least use a variety of habitat types in the landscape.

8. Populations of amphibians are regulated by a variety of factors, environmental and biological. Understanding the dynamics of amphibian populations and communities requires information on environmental parameters and data on predators and prey resources. Future work on such factors on military installations that already have baseline data on amphibian populations would yield considerable insight into dynamics over time and among habitats.

PRELIMINARY MANAGEMENT RECOMMENDATIONS

The following management recommendations were based on results from the first year's work. They are repeated here in slightly modified form influenced by observations and results from the second year of study in Dare County Bombing Range.

1. If the primary management goal for amphibians is to maintain the current level of species richness, then a mosaic of habitats is required. This is because some species do better in full canopy forests and some do better in more open habitats (e.g., Werner and Glennemeier, 1999). However, conversion of natural forested habitat to open canopy areas should be considered upon completion of a thorough review of the effects of such operations on all aspects of amphibian biology and ecology.

2. Because no legally protected (state or federal) species was found in Dare County Bombing Range thus far, the amphibian fauna should be managed as communities and not as single

species. Although some species appear to be rarely encountered, they should not yet be considered rare and specifically managed to enhance their population. Single species management may not be the best approach with the amphibian fauna in this area.

3. Monitoring of the amphibian fauna is likely to reveal habitat distribution and population dynamic patterns that will be useful to resource managers. Because patterns change with habitat change and over time, monitoring of this fauna should be considered a long-term effort. The three-year baseline data set obtained in this study will provide the basis for evaluation of changes in the future. Funding should be targeted for continuation of monitoring programs after the Legacy Resource Management Program support has ended.

4. Silvicultural practices on Dare County Bombing Range occasionally use herbicides as part of the management package. Ecotoxicology studies of effects of these chemicals on amphibians have not been thorough and often use only a laboratory species not found in North America (McDiarmid and Mitchell, 2000). Studies of the effects of spraying herbicides in both terrestrial and wetland habitats should continue and should target early life history stages (e.g., tadpoles). Such studies could reveal where chemical application is not harmful, where it may be harmful, and assist in developing the appropriate concentration levels to allow silvicultural use and simultaneously minimize or eliminate the effects on these sensitive species.

5. The natural hydroperiod of the pocosin habitat should be restored to the extent possible. The amphibians in the area have long been adapted to the natural hydrological fluctuations. We do not know if the amphibian community will remain the same as it is today once restoration has occurred, but long-term studies using this study as a baseline would reveal such changes, if any.

6. The introduction of non-native and invasive species of plants and animals should be resisted. This could include North American “native” species found outside of eastern North Carolina that could be harmful to amphibians.

7. Captive-raised or captive-bred amphibians should not be released in this area under any circumstances. The potential for disease introduction is growing and every effort should be made

to avoid contamination from exotics or native species from other areas. Captivity often induces stress and influences development of disease.

8. It would be advisable to review existing management activities that affect the habitat and hydrology of the area with management of amphibian communities and populations in mind. Such reviews may reveal conflicts that could be avoided or mediated if detected before problem arise.

9. It would also be advisable to review the myriad of wildlife management programs that are being used on Dare County Bombing Range to identify activities that may be in conflict with management activities focusing on amphibians.

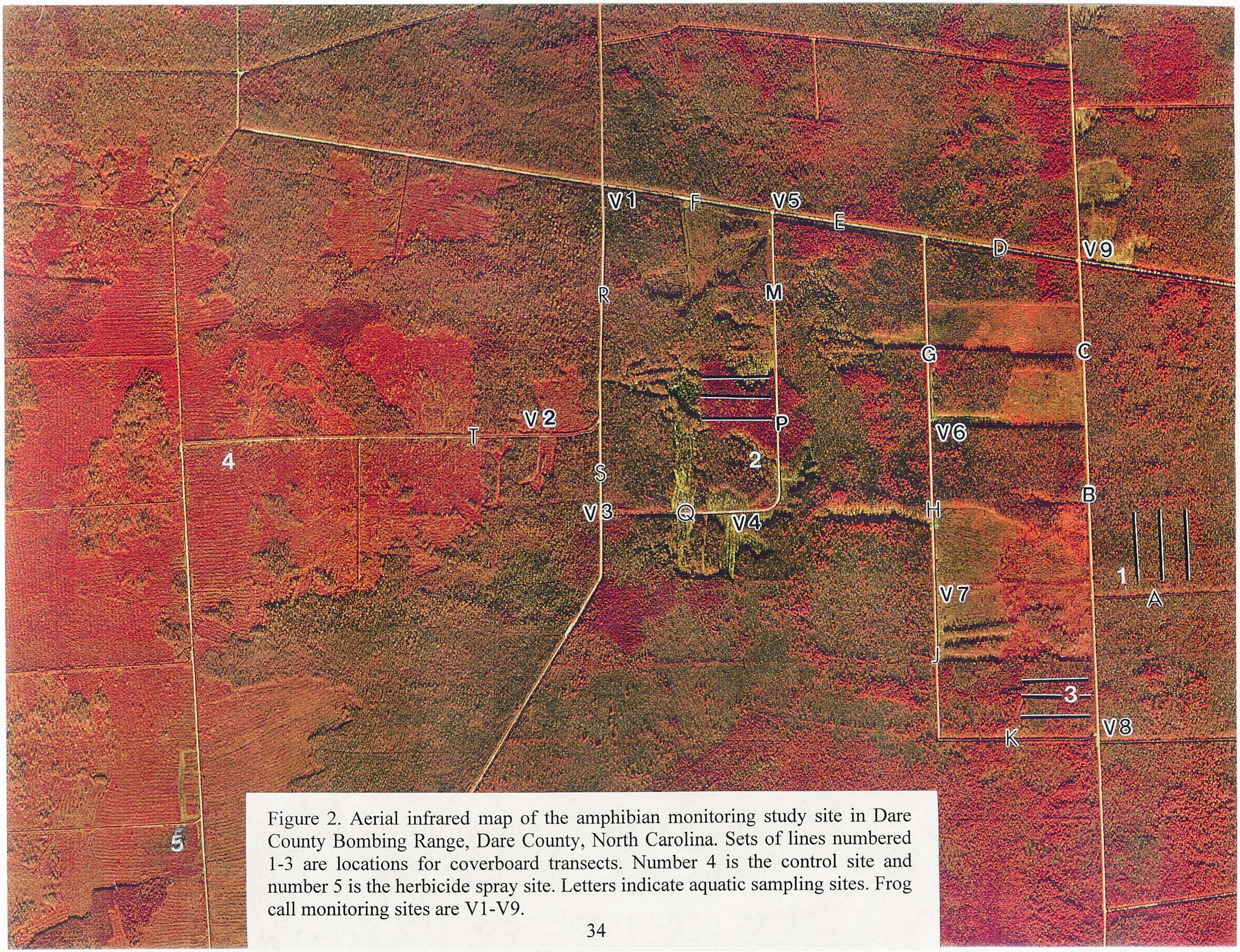

Figure 2. Aerial infrared map of the amphibian monitoring study site in Dare County Bombing Range, Dare County, North Carolina. Sets of lines numbered 1-3 are locations for coverboard transects. Number 4 is the control site and number 5 is the herbicide spray site. Letters indicate aquatic sampling sites. Frog call monitoring sites are V1-V9.

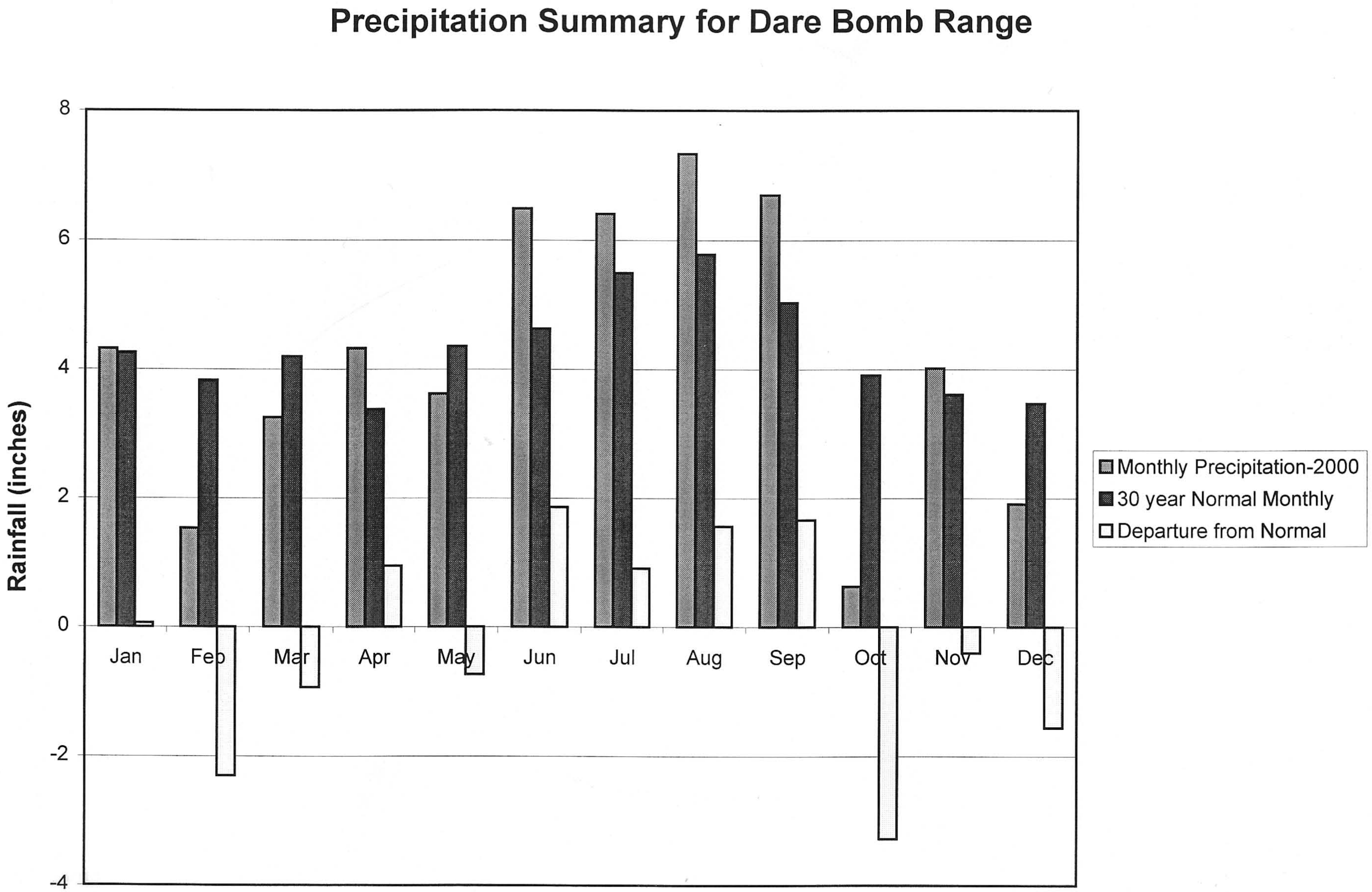

Figure 3. Monthly precipitation totals, 30-year averages, and departure from normal for Dare County, NC in 2000. Departure from normal is the difference between the monthly total for 2000 and the 30-year average. Data were from the U.S. Weather Service stations located along the Alligator River approximately 3.5 miles west of the study area in Dare County Bombing Range.

Table 1. Water chemistry (pH) values for selected aquatic sampling sites on Dare County Bombing Range in 2000.

	Site								
Month	B	C	D	E	G	J	K	Q	T
July	3.96	4.06	4.23	5.34	5.08	4.52	5.21	4.39	5.25
August	4.26	4.50	4.89	4.73	4.65	4.69	4.90	4.24	4.96
September	4.68	4.56	4.06	4.73	5.01	4.33	4.78	4.30	5.05
October	4.05	4.02	6.06	6.10	6.03	5.50	5.21	7.28	5.68

Table 2. List of amphibian species encountered on Dare County Bombing Range, Dare County, North Carolina in 1999 and 2000.

Anura (Frogs and Toads)	
Bufonidae:	
Bufo terrestris	Southern Toad
Hylidae:	
Acris gryllus gryllus	Coastal Plain Cricket Frog
Hyla chrysoscelis	Cope's Gray Treefrog
Hyla cinerea	Green Treefrog
Hyla femoralis	Pine Woods Treefrog
Hyla squirella	Squirrel Treefrog
Pseudacris crucifer crucifer	Northern Spring Peeper
Pseudacris ocularis	Little Grass Frog
Microhylidae:	
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad
Pelobatidae:	
Scaphiopus holbrookii	Eastern Spadefoot
Ranidae:	
Rana catesbeiana	American Bullfrog
Rana clamitans melanota	Northern Green Frog
Rana sphenocephala utricularia	Southern Leopard Frog
Rana virgatipes	Carpenter Frog
Caudata (Salamanders)	
Amphiumidae:	
Amphiuma means	Two-toed Amphiuma
Plethodontidae:	
Plethodon chlorobryonis	Atlantic Coast Slimy Salamander
Stereochilus marginatus	Many-lined Salamander
Salamandridae:	
Notophthalmus viridescens dorsalis	Broken-Striped Newt

Table 3- Number of amphibians captured at Dare County Bombing Range, NC in 2000 listed by life history stage.

	SEX/ LIFE HISTORY STAGE					
	sex unknown	Male	Female	Juvenile	Larvae	Total
Frogs						
A. gryllus	2	4				6
B. terrestris	1	8	5	1		15
H. chrysoscelis	4	101	28	5	3	141
H. cinerea	1	17				18
H. femoralis	1	6	6	1	1	15
H. squirella		1	1			2
R. catesbeiana			1		14	15
R. clamitans	36	112	126	317	771	1362
R. spenocephala	1	98	202	56	600	957
R. virgatipes	6	55	14	51	79	205
Salamanders						
A. means	22		1			23
P. chlorobryonis	42	9	7	2		60
Total	116	411	391	433	1468	2819

Table 4- Species occurrence by sampling technique at Dare County Bombing Range in 2000.

	SAMPLING TECHNIQUE					
	Artificial Cover Transects	PVC Pipe Transects	Visual Encounter Surveys	Minnow Trapping	Dip Nets	Frog Call Surveys
Frogs						
A. gryllus	X		X		X	X
B. terrestris	X		X	X		X
G. carolinensis			X			X
H. chrysoscelis	X	X	X	X		X
H. cinerea		X	X			X
H. femoralis	X	X	X	X		X
H. squirella		X	X			X
P. crucifer						X
P. ocularis						X
R. catesbeiana			X	X	X	X
R. clamitans	X		X	X	X	X
R. spenocephala	X		X	X	X	X
R. virgatipes	X		X	X	X	X
S. holbrookii			X			
Salamanders						
A. means				X		
P. chlorobryonis	X		X			

Table 5. Number of amphibians captured in coverboard transects at Dare County Bombing Range in 2000. Column heading numbers represent coverboard transect numbers.

	SITE NUMBER									
	1300	1400	1500	1600	1700	1800	1900	2000	2100	Total
Frogs										
A. gryllus					1					1
R. clamitans	5	3		4	3	9	3	15	17	59
R. sphenocephala						1				1
R. virgatipes			1							1
Salamanders										
P. chlorobryonis	1			10	10	19	3			43
Total	6	3	1	14	14	29	6	15	17	105

Table 6. Number of amphibians captured in PVC pipe transects at Dare County Bombing Range in 2000. Transect number refers to coverboard transects along which the PVC pipes were set (10 per transect). Transects 1300 and 1500 yielded no captures.

	TRANSECT NUMBER							
	1400	1600	1700	1800	1900	2000	2100	Total
Frogs								
H. chrysoscelis		18	6	1	4	3		32
H. cinerea		2						2
H. femoralis	1	1	1	7	2		1	13
H. squirella			1					1
Total	1	21	8	8	6	3	1	48

Table 7. Number of amphibians captured during Visual Encounter Surveys at Dare County Bombing Range in 2000. Numbers 1600 and 2100 represent coverboard transects. AWCS refers to a young juniper stand that was sprayed with herbicide in 1999. Sites A through Q represent small ephemeral pools and canals adjoining study area roads (see text for site descriptions).

	SITE NUMBER													
	1600	2100	AWCS	A	D	E	F	G	J	K	M	P	Q	Total
Frogs														
A. gryllus		1		1						1				3
B. terrestris					5	3	1			2	2		2	15
H. chrysoscelis	1					1				83	8	6		99
H. cinerea											16			16
H. squirella										1				1
R. catesbeiana	1													1
R. clamitans	1			4	17	83	23	60	3	51	72	62	37	413
R. sphenocephala				2	44	66	17	26	5	36	76	40	25	337
R. virgatipes			1		1	12	10	2			1	1	4	32
Salamanders														
P. chlorobryonis				1				1						2
Total	3	1	1	8	67	165	51	89	8	174	175	109	68	919

Table 8. Number of amphibians captured in minnow traps at Dare Bomb Range in 2000. Site numbers 1300-2100 refer to coverboard transects (traps were set in pools along the transect when wet). Sites A through T represent ephemeral pools and canals adjoining study area roads. The spray and control areas represent young Atlantic white cedar stands, one sprayed with herbicide and a control (similar site but not sprayed). Species abbreviations: Hch = *Hyla chrysoscelis*, Hfe = *Hyla femoralis*, Rca = *Rana catesbeiana*, Rcl = *Rana clamitans*, Rsp = *Rana sphenocephala*, Rvi = *Rana virgatipes*, Ame = *Amphiuma means*.

Site	Hch	Hfe	Rca	Rcl	Rsp	Rvi	Ame	trap days	Total
1300				19	8	17		85	44
1400				25	8	25		69	58
1500				53	4	24		127	81
1600	1			55	2	1		25	59
1700				25	2			14	27
1800				36	1			22	37
1900				15				10	15
2000				2				10	2
2100					1			12	1
spray			1	77	58	50	2	178	188
control			2	193	158	17	1	197	371
A				7	9			59	16
B							1	20	1
C				2	1			47	3
D				11	6	4	3	130	24
E	2			3	14	3		93	22
F					4	11		68	15
G				6	27	1	1	61	35
H	3		3	17	20	2	2	82	47
J			4	13	26	1		71	44
K				123	69	3	6	71	201
M				16	16		5	53	37
P	2			72	44	8		84	126
Q		1		46	26	2	1	49	76
R			2	13	18			29	33
S				13	34		1	37	48
T				17	76	2		34	95
Total	8	1	12	859	632	171	23	(1737)	1706

Table 9. Relative abundance of amphibians and predatory invertebrates in transect 1300 on Dare County Bombing Range in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
R. clamitans	15.00	0.00	44.44	0.00	7.50	2.78	0.00	5.00
R. sphenocephala	15.00	0.00	0.00	0.00	0.00	4.17	0.00	10.00
R. virgatipes	5.00	0.00	22.22	0.00	10.00	5.56	0.00	20.00
Invertebrates								
Crayfish	10.00	0.00	22.22	0.00	35.00	2.78	0.00	75.00
Pre. Diving beetle	0.00	0.00	11.11	0.00	0.00	0.00	0.00	5.00

Table 10. Relative abundance of amphibians and predatory invertebrates in transect 1400 at Dare County Bombing Range in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
R. clamitans	0.00	0.00	0.00	100.00	45.00	5.56	1.47	0.00	10.00
R. sphenocephala	0.00	0.00	0.00	0.00	0.00	0.00	4.41	0.00	25.00
R. virgatipes	0.00	0.00	0.00	8.33	30.00	5.56	11.77	0.00	45.00
Invertebrates									
Crayfish	0.00	0.00	0.00	41.67	155.00	11.11	23.53	0.00	60.00
Pre. Diving beetle	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00

Table 11. Relative abundance of amphibians and predatory invertebrates in transect 1500 at Dare County Bombing Range in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
R. clamitans	46.67	52.78	28.57	17.65	8.82	2.78	0.00	0.00
R. sphenocephala	3.33	5.56	3.57	0.00	0.00	0.00	0.00	0.00
R. virgatipes	10.00	16.67	7.14	5.88	8.82	2.78	0.00	25.00
Invertebrates								
Crayfish	0.00	5.56	7.14	214.70	14.71	27.78	0.00	15.00
Pre. Diving beetle	0.00	5.56	7.74	14.71	0.00	0.00	0.00	0.00

Table 12. Number of amphibians captured during dipnet surveys at Dare County Bombing Range in 2000. Numbers 1300 and 1500 represent coverboard transects. Sites E through R represent ephemeral pools and canals adjoining study site roads.

	SITE NUMBER											
	1300	1500	E	F	G	J	K	M	P	Q	R	Total
Number of sweeps per site:	32	35	12	15	4	18	16	10	20	18	10	190
A. gryllus							1					1
R. catesbeiana						1			1			2
R. clamitans	2	2		1	2		4	4	8		2	25
R. sphenocephala				1		2	1	1	3	2	2	12
R. virgatipes			1									1
Total	2	2	1	2	2	3	6	5	12	2	4	41

Table 13. Amphibian species in each of nine frog call monitoring stations on Dare County Bombing Range, NC, identified by vocalizations (V). Abbreviations for each species in parentheses are for the following tables.

	Sites								
Species	1	2	3	4	5	6	7	8	9
Frogs:									
Acris gryllus (Agr)	V	V	V	V	V	V	V	V	V
Bufo terrestris (Bte)			V		V	V	V	V	V
Gastrophryne carolinensis (Gca)	V				V			V	
Hyla chrysoscelis (Hch)	V	V	V	V	V	V	V	V	V
Hyla cinerea (Hci)	V	V	V	V	V	V			
Hyla femoralis (Hfe)			V	V	V	V	V	V	V
Hyla squirella (Hsq)						V	V		V
Pseudacris brimleyi (Pbr)							V		V
Pseudacris crucifer (Pcr)	V		V	V	V	V	V	V	V
Pseudacris ocularis (Poc)									V
Rana catesbeiana (Rca)	V		V	V	V	V	V		V
Rana clamitans (Rcl)	V	V	V	V	V	V	V	V	V
Rana sphenocephala (Rsph)	V	V	V		V	V	V	V	V
Rana virgatipes (Rvir)	V	V	V	V	V	V	V	V	V

Table 14. Seasonal variation in timing of male frog vocalizations at Site 1 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

						Species							
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27														
March 5														
March 12									V					
March 19									V					V
March 26	V								V				V	
April 2														V
April 9	V													V
April 16	V													V
April 23	V													V
April 30	V													V
May 7	V													V
May 14	V													V
May 21	V													V
May 28														
June 4	V			V	V									V
June 11	V			V	V									V
June 18	V			V	V						V			V
June 25														
July 2	V											V	V	V
July 9	V											V		V
July 16	V			V	V									V
July 23	V		V	V								V		V
July 30	V													V
August 6	V											V	V	V
August 13												V		
August 20												V	V	
August 27														

Table 15. Seasonal variation in timing of male frog vocalizations at Site 2 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27														
March 5														
March 12														
March 19														
March 26	V													
April 2	V													V
April 9	V											V		V
April 16	V													V
April 23	V													V
April 30	V													V
May 7	V													V
May 14	V													
May 21	V													V
May 28														
June 4	V			V										V
June 11	V			V										
June 18	V											V		
June 25														
July 2	V											V		V
July 9	V											V		V
July 16	V			V										
July 23	V			V	V							V		V
July 30	V													
August 6	V											V		
August 13				V										
August 20												V	V	
August 27														

Table 16. Seasonal variation in timing of male frog vocalizations at Site 3 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

Week of	Species													
	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27														
March 5														
March 12									V					
March 19									V				V	
March 26									V					V
April 2														
April 9	V													
April 16	V													V
April 23	V													V
April 30	V													V
May 7	V	V												V
May 14	V													V
May 21	V													V
May 28														
June 4	V			V										V
June 11	V			V								V		V
June 18	V			V								V		V
June 25														
July 2	V		V									V		V
July 9	V										V	V		V
July 16	V													
July 23	V			V	V							V		V
July 30	V												V	V
August 6	V											V		V
August 13	V											V		
August 20												V	V	
August 27														

Table 17. Seasonal variation in timing of male frog vocalizations at Site 4 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27														
March 5														
March 12									V					
March 19														
March 26	V													V
April 2														V
April 9	V													V
April 16	V													V
April 23	V													V
April 30	V													V
May 7	V													V
May 14	V													V
May 21	V													V
May 2														
June 4	V			V		V						V		V
June 11	V					V								V
June 18	V					V						V		
June 25														
July 2	V				V	V						V		V
July 9	V											V		V
July 16	V													
July 23	V			V		V								V
July 30	V													
August 6	V											V		V
August 13	V											V		
August 20														
August 27														

Table 18. Seasonal variation in timing of male frog vocalizations at Site 5 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27									V					
March 5									V					
March 12									V					
March 19													V	
March 26	V								V					V
April 2	V													V
April 9	V								V					V
April 16	V													V
April 23	V	V							V					V
April 30	V	V		V							V			V
May 7	V	V		V										V
May 14	V	V		V								V		V
May 21	V			V								V		V
May 28														
June 4	V		V	V								V	V	V
June 11	V		V	V	V									
June 18	V		V	V	V							V		V
June 25														
July 2	V				V							V	V	
July 9	V			V	V							V	V	V
July 16	V										V			
July 23	V		V	V	V		V					V		
July 30	V		V		V							V		V
August 6	V											V	V	V
August 13	V													
August 20												V		
August 27														

Table 18. Seasonal variation in timing of male frog vocalizations at Site 5 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27									V					
March 5									V					
March 12									V					
March 19													V	
March 26	V								V					V
April 2	V													V
April 9	V								V					V
April 16	V													V
April 23	V	V							V					V
April 30	V	V		V							V			V
May 7	V	V		V										V
May 14	V	V		V								V		V
May 21	V			V								V		V
May 28														
June 4	V		V	V								V	V	V
June 11	V		V	V	V									
June 18	V		V	V	V							V		V
June 25														
July 2	V				V							V	V	
July 9	V			V	V							V	V	V
July 16	V										V			
July 23	V		V	V	V		V					V		
July 30	V		V		V							V		V
August 6	V											V	V	V
August 13	V													
August 20												V		
August 27														

Table 19. Seasonal variation in timing of male frog vocalizations at Site 6 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27									V				V	
March 5									V				V	
March 12									V				V	
March 19									V				V	
March 26									V				V	V
April 2													V	V
April 9	V	V							V			V	V	V
April 16	V										V		V	V
April 23	V											V	V	V
April 30	V			V										V
May 7	V			V								V		V
May 14	V			V	V							V		
May 21	V											V		V
May 28														
June 4	V			V	V	V	V				V	V		V
June 11	V			V	V									V
June 18	V			V	V	V						V		V
June 25														
July 2	V					V					V		V	V
July 9	V					V					V	V	V	V
July 16	V			V										V
July 23	V			V	V	V	V				V			V
July 30	V				V						V	V		
August 6	V				V		V				V	V		V
August 13	V											V		
August 20		V										V	V	
August 27												V		

Table 20. Seasonal variation in timing of male frog vocalizations at Site 7 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27														
March 5														
March 12									V					
March 19									V					
March 26								V	V					
April 2														
April 9	V	V							V					
April 16	V													V
April 23	V													V
April 30	V	V												V
May 7	V											V		V
May 14	V	V												
May 21	V													V
May 28														
June 4	V			V		V						V		
June 11	V											V		V
June 18	V					V						V		V
June 25														
July 2	V											V	V	V
July 9	V										V	V	V	V
July 16	V													
July 23	V			V		V	V					V		
July 30	V											V		
August 6	V											V		V
August 13														
August 20												V		
August 27												V		

Table 21. Seasonal variation in timing of male frog vocalizations at Site 8 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27														
March 5														
March 12									V					
March 19														
March 26	V													V
April 2									V					
April 9		V							V				V	
April 16	V													V
April 23	V	V												V
April 30	V	V												V
May 7	V	V												V
May 14	V	V												V
May 21	V													V
May 28														
June 4	V													V
June 11	V											V		V
June 18	V				V							V		V
June 25														
July 2	V											V	V	V
July 9	V											V		V
July 16	V													
July 23	V		V	V										V
July 30	V											V		V
August 6	V		V	V								V		V
August 13	V													
August 20		V										V		
August 27														

Table 22. Seasonal variation in timing of male frog vocalizations at Site 9 on the Dare County Bombing Range, NC for 2000. Species abbreviations as in Table 13.

Week of	Species													
	Agr	Bte	Gca	Hch	Hci	Hfe	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp	Rvir
February 27								V	V					
March 5								V	V					
March 12									V					
March 19									V					
March 26								V	V				V	
April 2									V					
April 9		V							V					
April 16	V								V		V			V
April 23	V	V												V
April 30	V			V							V			V
May 7	V	V								V				V
May 14	V	V		V										V
May 21	V													V
May 28														
June 4	V			V		V								V
June 11	V			V										V
June 18	V			V		V	V					V		V
June 25														
July 2	V										V	V		V
July 9	V										V	V	V	V
July 16	V													
July 23	V			V		V	V			V	V			
July 30	V										V			
August 6	V		V	V		V	V			V	V			
August 13	V			V		V					V			
August 20												V		
August 27														

Table 23. Number of amphibians marked at Dare County Bombing Range, NC in 2000 by life history stage.

	SEX AND LIFE HISTORY STAGE			
	Male	Female	Juvenile	Total
Frogs				
B. terrestris	6	5		11
H. chrysoscelis	93	6	5	104
H. cinerea	17			17
H. femoralis	1	4	1	6
H. squirella	1	1		2
R. catesbeiana		1		1
R. clamitans	104	147	237	488
R. sphenocephala	95	193	54	342
R. virgatipes	50		35	85
Total	367	357	332	1056

Table 24. Recapture locations and minimum distances moved for frogs on Dare County Bombing Range, NC in 2000. Sites A and B in coverboard and PVC transect 2100 refer to first and second halves of the transect, respectively.

Species	Location Marked	Location Recaptured	Distance (m)
H. femoralis	2100B	2100A (PVC 2106)	100
R. clamitans	site F	site E	150
R. sphenocephala	site P	site Q	160
R. sphenocephala	1300B	site M	380

RESULTS FOR CHERRY POINT MARINE CORPS AIR STATION

INTRODUCTION

Cherry Point Marine Corps Air Station lies in Craven County, North Carolina, adjacent to the town of Havelock It is bordered by the Neuse river to the north, Slocomb creek to the west, Hancock creek to the east, and U. S. highway 70 and N.C. Highway 102 to the south. Cherry Point MCAS was established originally in 1941 as Cunningham Field but the name changed to Cherry Point in 1942. The installation consists of 13,320 acres, of which approximately 6,000 are used as runways, aircraft hangers, and other maintenance and support installations. Approximately 3,200 acres are forested and managed for timber production, hunting and wildlife benefits. The majority of these forested areas are characterized by a mix of wet pine flatwoods, swamp forest, and small, isolated depressional wetlands.

Amphibian species richness expected for the region that includes Cherry Point MCAS is based on species distribution maps in Conant and Collins (1998), and include 22 species of frogs and toads and 14 species salamanders. During the 1999-2000 period we encountered 15 species of frogs and 4 species of salamanders, or 53% of the expected regional amphibian fauna (68% of frogs, 29% of salamanders). We used six standardized techniques to monitor amphibians in Cherry Point MCAS in 1999 and 2000. This report summarizes the results for 2000. Results from the monitoring project conducted in the field season of 1999 are in Mitchell (2000).

The objectives of the fieldwork in 2000 (largely FY 00) were primarily to expand the baseline data on amphibian occurrence and relative abundance obtained in 1999, and to evaluate seasonal changes in amphibian activity at selected sites. These complimented the overall project objectives.

STUDY SITE DESCRIPTIONS

Study site

Amphibian community and population monitoring was carried out at a series of small isolated wetlands (pools) and manmade impoundments (ponds) in an area generally bounded by Access Road to the south, Roosevelt Road to the west and north, and Hancock Creek to the north and east (**Figure 4**). Three wetland sites were located along the dirt road to the east of Range

Road leading to the end of the runway extending to the northeast. These sites lie north of the small arms range. Artificial cover transects were established at six locations in surrounding terrestrial habitats north of Access Road. Habitat descriptions for study ponds and for artificial cover transects are given below.

Habitat

The dominant terrestrial habitat type in mainland Craven County, North Carolina, is mixed hardwood and pine forest. The habitat in the study area on Cherry Point MCAS was mostly upland pine flatwoods with patches of mixed hardwoods and vegetation characteristic of riparian systems along creeks. The study area consisted mostly of open loblolly pine (*Pinus taeda*) flatwoods with an understory of red maple (*Acer rubrum*) and mixed oaks (*Quercus* spp.) and a thick ground cover of mixed grasses and blueberry (*Vaccinum* spp.). One area in which we conducted a plant ecology transect was dominated by mixed hardwoods but it was harvested for timber in January 2000 and converted to pine flatwoods. Amphibian monitoring sites in the wetlands of the study area include highly ephemeral pools in open areas (created by vehicular traffic and an old telephone line right-of-way), permanent impoundments, small sinkhole ponds, and a riparian area along a small creek. The pocosin habitat characteristic of Dare County Bombing Range does not occur at Cherry Point.

Precipitation Summary for 2000

The precipitation summary for 2000 was considerably different than that for 1999 when drought conditions prevailed in summer months until hurricanes Floyd and Dennis brought abundant rainfall and refilled all dry pools and ponds. For six months in 2000, Cherry Point received greater than normal precipitation (**Figure 5**). Substantially greater than normal rainfall fell in September, and close to the 30-year average amount fell in July. Only during the months of February, May, June, October, and December was precipitation more than a trace lower than normal. Most pools and ponds contained water year round in 2000. Most pools and ponds retained water throughout the study in 2000.

Terrestrial Habitat Descriptions

In 1999, six 300 meter-long artificial coverboard transects were established in forested areas near and around study ponds to gather data on inter-pond movements of amphibians and to monitor populations of amphibians that are largely or wholly terrestrial. Results of the plant ecology analyses that were conducted along these transects were included in Mitchell (2000) and are not repeated here. Vegetation analysis revealed few significant differences among the six established coverboard transects. Thus, the following descriptions apply to the area in which the terrestrial work was conducted and in which the pools and ponds we have studied are located.

The forest surrounding the study pools and ponds can be described as wet pine flatwoods. The overstory is dominated by loblolly pine (*Pinus taeda*). Other overstory trees are sweetgum (*Liquidambar styraciflua*), red bay (*Persia borbonia*), red maple (*Acer rubrum*), and several species of oaks (*Quercus* spp.). The most abundant understory tree is sweetgum. All transects except transect "B" contained conspicuous stands of cane (*Arundinaria gigantea*). Forbs, especially several species of thoroughwort (*Eupatorium* spp.), are present but not abundant.

Various portions of the study area were burned and logged between 1984 and 2000. During our study the areas around isolated wetlands Site 1 and coverboard transect A were burned with a low intensity prescribed burn. The lower portion of coverboard transect C was logged extensively in early 2000. The effects these actions have had on the amphibians of the area await further analysis.

Aquatic Habitat Descriptions

Physical and vegetation characteristics of most of the ponds in the study area are generally similar. They are grouped together under the appropriate habitat descriptions given here. Those exhibiting significant habitat differences are treated separately. Descriptions are repeated here in abbreviated form, whereas complete descriptions are in Mitchell (2000). Pool and pond numbers correspond to those in **Figure 4**.

Pools 1, 3, 4 - These isolated wetlands are all small, vernal pools exhibiting moderate amounts of aquatic, emergent vegetation and organic matter in the substrate. Emergent vegetation consists of water lilies and pickerel weed (*Pontaderia cordata*). The surrounding forest is dominated by loblolly pine (*Pinus taeda*). These pools are shaded by canopy cover. Pool 1 was near neutral to slightly basic with acidity levels varying from 7.19 to 8.83 (**Table 25**). Pool 3 was slightly acidic (pH 5.85-7.24) and pool 4 was generally acidic throughout the year (pH 5.13-5.89).

Pools 2, 11 - These two wetlands are elongate, shallow pools associated with small streams. They are heavily vegetated and shaded by surrounding forest cover. Each of these pools contained water throughout our sampling period in 2000. No pH readings were taken in 2000.

Ponds 5, 15 - These ponds are large, relatively deep (> 2m in some places), open, man-made impoundments, created mostly for fishing and other types of outdoor recreation. Some emergent vegetation occurs along the edges of these ponds but most is found at the outfalls, where the ponds flow outwards to Slocomb creek. The surrounding forest is relatively open and park-like. The area is used by people engaging in outdoor activities. No pH readings were taken in 2000.

Pool 6 - This isolated wetland is derived from a series of wheel ruts in an open grassy area at the northwestern edge of our study area. There is little to no emergent vegetation and surrounding vegetation is limited to low grass cover. The substrate is primarily a muddy clay. Although this is the most exposed site in our study area, several of the pools contained water, albeit small amounts, during the entire sampling period in 2000. Water chemistry varied from slightly acidic (pH 5.98) to slightly basic (pH 8.81) in 2000 (**Table 25**).

Pool 7 - This is a small, nearly circular pool lying just within the forest that borders a cleared grassy area at the northwestern end of the study area. It resembles several other pools in the study area (e.g., ponds 1, 3 and 4), but is deeper (> 1m) and features a conspicuous raft of grasses and water lilies. This pond contained water throughout our sampling period in 1999 and 2000. It was acidic for most of 2000 with pH values ranging from 5.21 to 7.08 (**Table 25**).

Pool 8 - This is a shallow pool associated with a small stream that crosses the abandoned telephone right-of-way. It measures approximately 20m x 4m. The substrate is thick clay with an abundance of organic matter. There is little emergent vegetation. This pond is well-shaded and receives large amounts of leaf-litter. The pool retained water throughout 2000. It was acidic throughout 2000 with pH values ranging from 4.34 to 5.45 (**Table 25**).

Pools 10, 13, 14 - These isolated pools were formed in shallow, wheel ruts along the right-of-way for an old, abandoned telephone line. These are shallow (< 0.5m), clear pools with a few emergent grasses and small amounts of mosses along their margins. Most of these pools retained water throughout 2000. Pool 10 was impacted by heavy logging equipment (bulldozer) in 2000 but was not completely destroyed. Acidity in Pool 10 varied from 5.89 to 6.63 (**Table 25**). Pool 13 was generally acidic in 2000 with pH values ranging from 4.84 to 5.94. No readings were taken from pool 14.

Pond 12 - This wetland lies just off the paved road leading to Hancock Creek housing area and Marina and is the upper end of a shallow creek. It is extensive, approximately 60m x 20m in area, but is relatively shallow (< 1m). It is well shaded with some emergent grasses, especially along its western shore and relatively closed canopy of trees. This wetland dried out completely during the summer of 1999 but retained water during all of 2000. It was slightly acidic in 2000 with pH values varying from 5.60 to 7.08 (**Table 25**).

Pond 16 - This wetland lies adjacent to a strip of cleared land fronting the northeast runway on the air station. It is large and deep (>1m). It was formed by beaver activity. Emergent vegetation is heavy, with numerous logs, sticks, and tree snags throughout. Marginal vegetation includes alder (*Alnus* sp.), sweetgum (*Liquidambar styraciflua*), and numerous forbs and grasses. A few stands of cattails (*Typha* sp.) are present. This pond contained water throughout the 2000 sampling period. No pH readings were taken in 2000.

RESULTS

To date a total of 15 species of frogs and 4 species of salamanders have been confirmed for the study area at Cherry Point MCAS (**Table 26**). In 2000, we encountered 14 species of frogs and three species of salamanders in the study area. We captured a total of 1,767 individuals as larvae, juveniles, or adult males or females (**Table 27**), compared to 920 individuals in 1999. Three species of frogs were captured in large numbers: *Hyla cinerea* (green treefrog), *Hyla squirella* (squirrel treefrog), and *Rana sphenocephala* (southern leopard frog) in the two consecutive years. Most green treefrogs and squirrel treefrogs captured were adults, whereas most southern leopard frogs captured were tadpoles. Total numbers for these three species accounted for 62% of all captures in 2000, similar to the 63.5% of the total for 1999. The broken-striped newt (*Notophthalmus viridescens*) was the most abundant of the three species of salamanders captured.

Most frogs were captured during the execution of four of the six standardized monitoring protocols we used at Cherry Point MCAS (**Table 28**) but all techniques yielded information on frogs. Only three species of amphibians, two frogs and one salamander, were encountered under artificial coverboards. This technique may not be useful for amphibians in this habitat. However, this technique has yielded numerous records of reptiles, especially snakes (Mitchell and field crew, unpublished). The species captured by the PVC pipe technique were all treefrogs, as would be expected for these isolated upright refugia. Oak toads (*Bufo quercicus*) were encountered only with one technique (frog call surveys), whereas all other species were captured by two or more techniques. Each of the three species of salamanders was captured by two techniques each.

Artificial coverboard transects yielded only nine individual and two species of frogs and four individuals of one salamander (**Table 29**). The frogs were distributed randomly among the transect sites, whereas the salamanders were captured in two of the six transects. These results are similar to those obtained in 1999.

PVC pipe transects proved to be a very useful monitoring technique for treefrogs at Cherry Point MCAS. A total of 554 adult individuals of four species of treefrogs was captured in 2000 (**Table 30**), compared to 257 captured in 1999. Of these, 63% were green treefrogs (*Hyla cinerea*), slightly lower than the 69.3% for this species in 1999. All PVC pipe transects and all individual pipes yielded treefrogs, suggesting that these amphibians are distributed throughout the terrestrial habitat in the study area. This result also suggests that treefrogs use such refugia extensively and raises the question whether such refugia might enhance treefrog population size in the area. It also raises the question of whether there are enough natural refugia and whether loss of trees from harvesting may impact treefrog populations.

A total of 327 individual amphibians were observed or caught during visual encounter surveys of the nine wetlands and terrestrial locations on Cherry Point MCS in 2000 (**Table 31**), compared to 199 in 1999. Four species were observed more commonly than the others, pine woods treefrog (*Hyla femoralis*), squirrel treefrog (*Hyla squirella*), bullfrogs (*Rana catesbeiana*), and spadefoot toads (*Scaphiopus holbrookii*). About half of the number of Cope's gray treefrogs

(*Hyla chrysoscelis*) seen in 1999 (37) were seen in 2000 (14). Only two salamanders were observed during visual encounter surveys. Number of species observed with this technique varied from 1 at wetland sites 3, 10, and 16 and two upland sites to 9 at wetland site 4. No amphibians were observed at site 8 in 1999 but five species were observed there in 2000.

The minnow trap technique was successful at capturing two or more species in 10 wetland sites. Total number of frogs captured in 2000 was 309, whereas the total was 457 in 1999 (**Table 32**). Most frog captures were tadpoles. Total number of salamanders captured in 2000 was 38, nearly identical to the number captured in 1999 (35). Numbers of captures for individual species varied from 1 (squirrel treefrog [*Hyla squirella*], spring peeper [*Pseudacris crucifer*], green frog [*Rana clamitans*]) to 200 (southern leopard frog, *Rana sphenocephala*). Broken-striped newts (*Notophthalmus viridescens*) outnumbered amphiuma (*A. means*) captures by 2:1. Number of frogs captured among wetlands varied from 3 at site 15 to 159 at site 4. Site 15 is an impoundment stocked with fish for recreation, whereas site 4 is a natural isolated wetland surrounded by forest and does not contain fish. Numbers of frogs captured at site 6 were higher in 1999 (193) than in 2000 (48), suggesting that the capacity of this road-rut system to support amphibians was altered in some way. We observed increased vehicular traffic in this area in 2000, including some ORV activity within the pools. Such activity causes mortality by displacing egg masses and tadpoles on to the banks. Number of individual salamanders captured in wetlands varied from 0 at site 13 to 19 in site 4.

Relative abundances of amphibians and predatory invertebrates captured in minnow traps varied dramatically among species and across time in three example locations (**Tables 33-35**). Predatory invertebrates were crayfish (*Procambarus acutus*), odonate larvae (dragonfly and damselfly nymphs), giant water bugs (*Lethocerus americanus*), predaceous diving beetles (*Cybister fimbriolatus*), and water scorpions (*Ranatra* spp.). Number of species of amphibians and invertebrate predator groups encountered was higher than numbers found in Dare County Bombing Range but similar to the diversity found at Camp Lejeune (see the respective sections in this report). Predator abundance in pools 4 and 10 was high in most sampling months and included all of the species and species groups. Most of the predators in pool 6 were crayfish, whereas other groups were present in small numbers in only one month out of the study period. Amphibian abundance was highest in pool 4. They were moderately abundant in pools 6 and 10. Amphibian and predator abundance was highest in the period of February through July in pool 4 and dominated by southern leopard frogs (*R. sphenocephala*). Amphibian abundances were highest in pool 6 in June through August and dominated by bullfrogs (*R. catesbeiana*) and treefrogs (*Hyla* spp.). Crayfish were abundant in pool 6 in all but one of the months sampled in 2000. In pool 10, amphibian abundances were relatively high February through April and moderately high in July through October. Southern leopard frog tadpoles dominated samples in most months except for April when spring peeper (*Pseudacris crucifer*) tadpoles were abundant and in August and September when treefrogs and cricket frog tadpoles dominated. Invertebrate abundances were variable throughout 2000 but dominated by crayfish in most months. Given these comparisons, the invertebrate predators in these pools undoubtedly exert a controlling effect on aquatic amphibians populations.

Dipnet surveys were conducted in nine of the wetland sites. A total of 477 individuals of 11 species of frogs and 49 individuals of one salamander species was captured in 2000 (**Table 36**), compared to 175 total individuals captured in 1999. Southern leopard frog (*Rana sphenocephala*) tadpoles dominated the numbers of tadpoles captured in both years (65% in 1999, 54% in 2000). Number of individual frogs and tadpoles captured among wetlands varied from 7 in site 12 to 206 in site 6. Number of species among wetlands ranged from one in site 8 to 8 in site 4. All 49 broken-striped newts (*N. viridescens*) were captured in site 4. This site was also the only location this salamander was captured in 1999.

The variation in relative abundances of amphibian larvae and predatory invertebrates captured in dipnet sweeps in three pools mirrored the variation seen in relative abundances obtained by the minnow trap technique (**Tables 37-39**). Amphibian larval abundance was highest in pool 4 in June and July reflecting the high densities of hylid tadpoles (**Table 37**). Tadpoles of early breeding frogs (southern leopard frogs and spring peepers) and the broken-striped newt dominated in spring months. Invertebrate predators were diverse and relatively abundance throughout most of the year in this wetland. The amphibian larval community in pool 6 was dominated by southern leopard frog tadpoles in June but was highly variable in other months (**Table 38**). Very few tadpoles were present in this pool in March-April and October, reflecting the highly seasonal use of this wetland. Only two invertebrate predators occurred in this pool in 2000; they were not observed until June. Amphibian larval relative abundance in pool 10 also reflected the highly variable hydrology of this shallow wetland (**Table 39**). Larvae in spring months were dominated by spring peepers and southern leopard frogs and in summer months by hylid tadpoles. Relative abundances were never as high as they were in the other two pools. Crayfish dominated the invertebrate predator community. The only other predator was the suite of dragonfly and damselfly nymphs and these were relatively low in number.

The weekly nighttime frog call survey yielded information on all 14 of the 15 species of frogs documented to date for Cherry Point MCAS (**Table 40**). Based on male vocalizations alone, this technique recorded 6 to 13 species present in these seven wetlands. Thirteen species called at one site (1), 9-11 called at five sites, and 6 called at one site (12). Dipnet and minnow trap results found tadpoles of several species in five of the seven sites monitored. **Tables 41-47** provide information on seasonal occurrence of the 14 species of frogs within each of the seven wetlands. There was considerable variation in when a particular species called at each wetland. For example, the southern cricket frog (*Acris gryllus*) called extensively in 1999 at four of the study sites but one to not at all at three others. Many species called for several weeks in a row, then skipped one or more weeks before calling again (e.g., barking treefrog [*H. gratiosa*], squirrel treefrog [*H. squirella*], southern leopard frog [*R. sphenocephala*]). Based on calling males, the frog fauna of Cherry Point MCAS appears to be dominated by six species: southern cricket frogs (*A. gryllus*), squirrel treefrogs (*H. squirella*), pine woods treefrogs (*H. femoralis*), Cope's gray treefrogs (*H. chrysoscelis*), spring peepers (*P. crucifer*), and southern leopard frogs (*R. sphenoceplaha*).

In 1999, we marked a total of 296 individual frogs by toe clipping at Cherry Point MCAS (Mitchell, 2000). In 2000, we marked an additional 417 individuals of 9 species (**Table 48**). Total number marked in both years was 713. The following species were marked: southern toads (*Bufo terrestris*), Cope's gray treefrog (*Hyla chrysoscelis*), green treefrog (*Hyla cinerea*), pinewoods treefrogs (*Hyla femoralis*), barking treefrog (*Hyla gratiosa*), squirrel treefrogs (*Hyla squirella*), bullfrogs (*Rana catesbeiana*), southern leopard frogs (*Rana sphenocephala*), and narrow-mouthed toads (*Gastrophryne carolinensis*).

In 2000, we recaptured 8 individual frogs of 5 species that we had marked previously in 1999 and 2000 (**Table 49**). Treefrogs moved from 30 to 130 meters from their original capture locations. The two terrestrial frog species (southern toad [*Bufo terrestris*] and southern leopard frog [*Rana sphenocephala*]) moved from 220 to 310 meters from their original points of capture. These preliminary data suggest that treefrogs move shorter distances than their terrestrial counterparts. They also suggest that these frogs use the landscape extensively and are not restricted to small areas.

DISCUSSION AND CONCLUSIONS

The frog fauna in our study area on Cherry Point MCAS consists primarily of species that breed in shallow, ephemeral bodies of water or use beaver ponds. All of these species use the surrounding forested habitat for shelter during most of the year except for mating and egg laying periods at the small wetlands characteristic of the installation. The only exception is the bullfrog (*Rana catesbeiana*) that breeds in permanent bodies of water, such as the impoundments. Juvenile bullfrogs are often found in ephemeral pools considerable distances from permanent water but such places do not support breeding populations. These juveniles, like those of green frogs (*Rana clamitans*) and southern leopard frogs (*Rana sphenocephala*), use the surrounding terrestrial habitat extensively (see movement results, above). Thus, both the aquatic and terrestrial habitats are essential to the long-term survival of these sensitive species on Cherry Point MCAS. Management of the remaining forest on the base by timbering operations may impact the size and dynamics of some of the amphibian populations through the reduction of non-breeding shelter locations.

Treefrogs use arboreal refugia (trees) extensively. Reduction in number of natural shelter sites by loss of trees, especially hardwood trees, may affect survival of some individuals and affect population sizes of some species. We found large numbers of treefrogs in the PCV pipes along our terrestrial transects. These pipes often contained several individuals, and they would immediately return to the pipe once they have been captured and released 1-3 meters away. A way to test the hypothesis that artificial refugia may increase treefrog population size is (1) conduct a mark-recapture of these frogs to determine current population size, then (2) add more PVC pipe refugia and follow the populations for 2-3 more years. A positive relationship of shelter abundance to frog breeding population size may have forest management implications and can be used to augment efforts to maintain or increase frog populations in an area.

I conclude from the results of the first two years of this study that our results will yield insights into how amphibians use the landscape in this area. Increasing the numbers of marked individuals during the second year (2000 field season) has resulted in the first observations of movement by several species. Thus, we already know that frogs disperse considerable distances through the forested habitat. The results from the third year based on the large number of marked individuals should reveal a better picture of movement distances at Cherry Point MCAS and help us to address management issues at the landscape level. Frogs in this area disperse large distances like many species do in other types of habitats (see reviews in Semlitsch, 1998; Pauley et al. 2000).

All of the wetland sites on Cherry Point MCAS we have studied support moderate to high levels of amphibian diversity. These sites and their surrounding terrestrial habitats are critical to the survival of these sensitive species. The preliminary movement data indicate that the forest surrounding these isolated wetlands are critical to the long term viability of amphibians in the area. The isolated wetlands are critical centers of diversity for these species because they are used by many species for reproduction. Thus, management of the amphibian fauna on Cherry Point MCAS should be addressed at the landscape level and not by targeting isolated wetlands or small tracts of forest.

Site 4 should be singled out because of its high species richness, high numbers of individuals, and the fact that it is surrounded by mixed forest. This site and a 150-160 meter buffer should be protected from extensive logging operations. This wetland supports an intact amphibian and invertebrate community. The examples presented in this report for Cherry Point MCAS show some of the diversity in predator and prey species richness and relative abundance. They demonstrate that some wetlands support more robust communities than others. Those wetlands should be targeted for special protection because they represent the best examples of natural systems in the area.

The following conclusions can be drawn from the results of the first two year's of research on the amphibians of Cherry Point MCAS:

1. The pine flatwoods, mixed pine and hardwood forest, and their associated ephemeral wetlands characteristic of our study area on Cherry Point MCAS support a rich diversity of amphibians.

2. A combination of monitoring and capture techniques is required to encounter the entire amphibian fauna. No one technique is useful to monitor all life history stages of all species.

3. The nighttime frog call survey is the best technique to assess the presence or absence of a frog species at ephemeral and permanent wetland sites, although it can say little about its reproductive use or success in a specific habitat or site.

4. Determination of whether a particular site is used for reproduction requires the use of the dip net and minnow trap techniques, as well as visual observation.

5. The amphibian fauna at Cherry Point MCAS is dynamic and species are active on different seasonal cycles. Monitoring of all species requires multiple techniques used over the entire season, including winter, to obtain information on all species present.

6. Preliminary information on distances moved by frogs in our study area on Cherry Point MCAS suggests that movements are not limited to small areas and can occur across large distance. This suggests that frogs use a variety of habitat types in the landscape.

7. Populations of amphibians are regulated by a variety of factors, environmental and biological. Understanding the dynamics of amphibian populations and communities requires information on environmental parameters and data on predators and prey resources. Future work on such factors on this installation with the existing baseline data on amphibian populations would yield considerable insight into population and community dynamics over time and among habitats.

8. Treefrog populations on Cherry Point MCAS appear to be robust. Determining how terrestrial refugia influence population size and dynamics could yield considerable insights into how forests may be managed with amphibians in mind. A mark-recapture project combined with the use of artificial refugia would yield very results and is recommended as a future project on this installation.

PRELIMINARY MANAGEMENT RECOMMENDATIONS

1. If the primary management goal for amphibians is to maintain the current level of species richness and at viable population sizes, then the diversity of terrestrial and wetland habitats should be maintained.

2. Because no legally protected (state or federal) species was found on Cherry Point MCAS thus far, the amphibian fauna should be managed as communities and not as single species. Although some species appear to be rarely encountered, they should not yet be considered rare and specifically managed to enhance their population. Single species management may not be the best approach with the amphibian fauna in this area.

3. Monitoring of the amphibian fauna is likely to reveal habitat distribution and population dynamic patterns that will be useful to resource managers. Because patterns change with habitat change and over time, monitoring of this fauna should be considered a long-term effort. The three-year baseline data set obtained in this study will provide the basis for evaluation of changes in the future. Funding should be targeted for continuation of monitoring programs after the Legacy Resource Management Program support has ended.

4. Ecotoxicology studies of effects of herbicides and pesticides on amphibians have not been thorough and often use only a laboratory species not found in North America (McDiarmid and Mitchell, 2000). Spraying herbicides and pesticides in and over terrestrial and wetland habitats could produce harmful results for amphibians, especially at the larval stage. Decisions to use chemicals in this are should be made with extreme caution.

5. The natural hydroperiod of the area should be maintained to the extent possible. The amphibians in this area have long been adapted to the natural hydrological fluctuations. Activities such as ditching and clearcutting that results in increased evaporation should be avoided when and where possible.

6. The introduction of non-native and invasive species of plants and animals should be resisted. This could include North American “native” species found outside of eastern North Carolina that could be harmful to amphibians.

7. Captive-raised or captive-bred amphibians should not be released in this area under any circumstances. The potential for disease introduction is growing and every effort should be made to avoid contamination from exotics or native species from other areas. Captivity often induces stress and influences development of disease.

8. It would be advisable to review existing management activities that affect the habitat and hydrology of the area with management of amphibian communities and populations in mind. Such reviews may reveal conflicts that could be avoided or mediated if detected before problem arise.

9. It would also be advisable to review the myriad of wildlife management programs that are being used on Cherry Point MCAS to identify activities that may be in conflict with management activities focusing on amphibians.

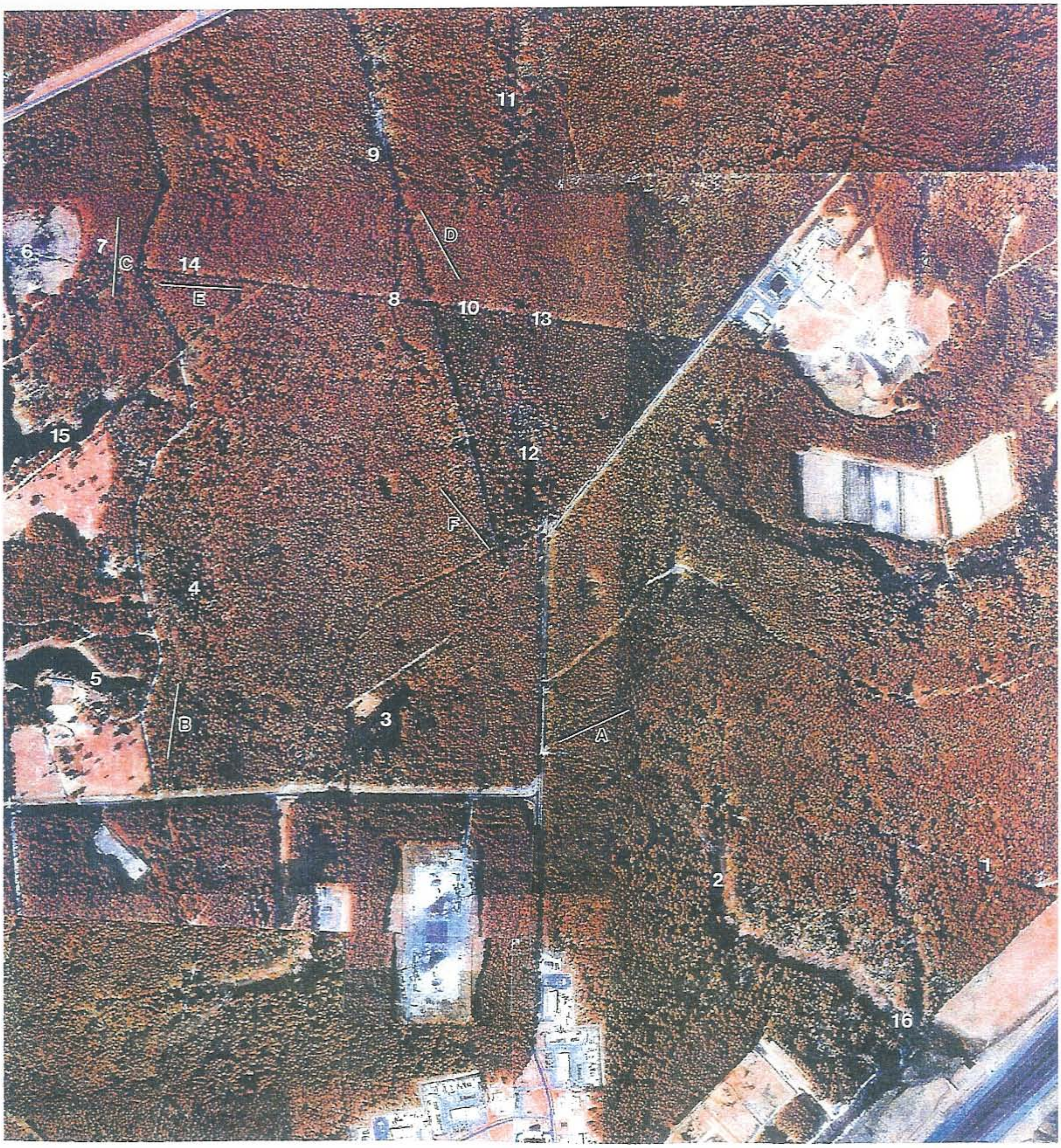

Figure 4. Aerial infrared map of the study area in Cherry Point MCAS, Craven County, North Carolina, illustrating locations of the 16 isolated wetland amphibian monitoring study sites (numbers) and the six coverboard sites (letters). Each letter corresponds with transect number listed in the following tables (A = 700, B = 800, C = 900, D = 1000, E = 1100, F = 1200).

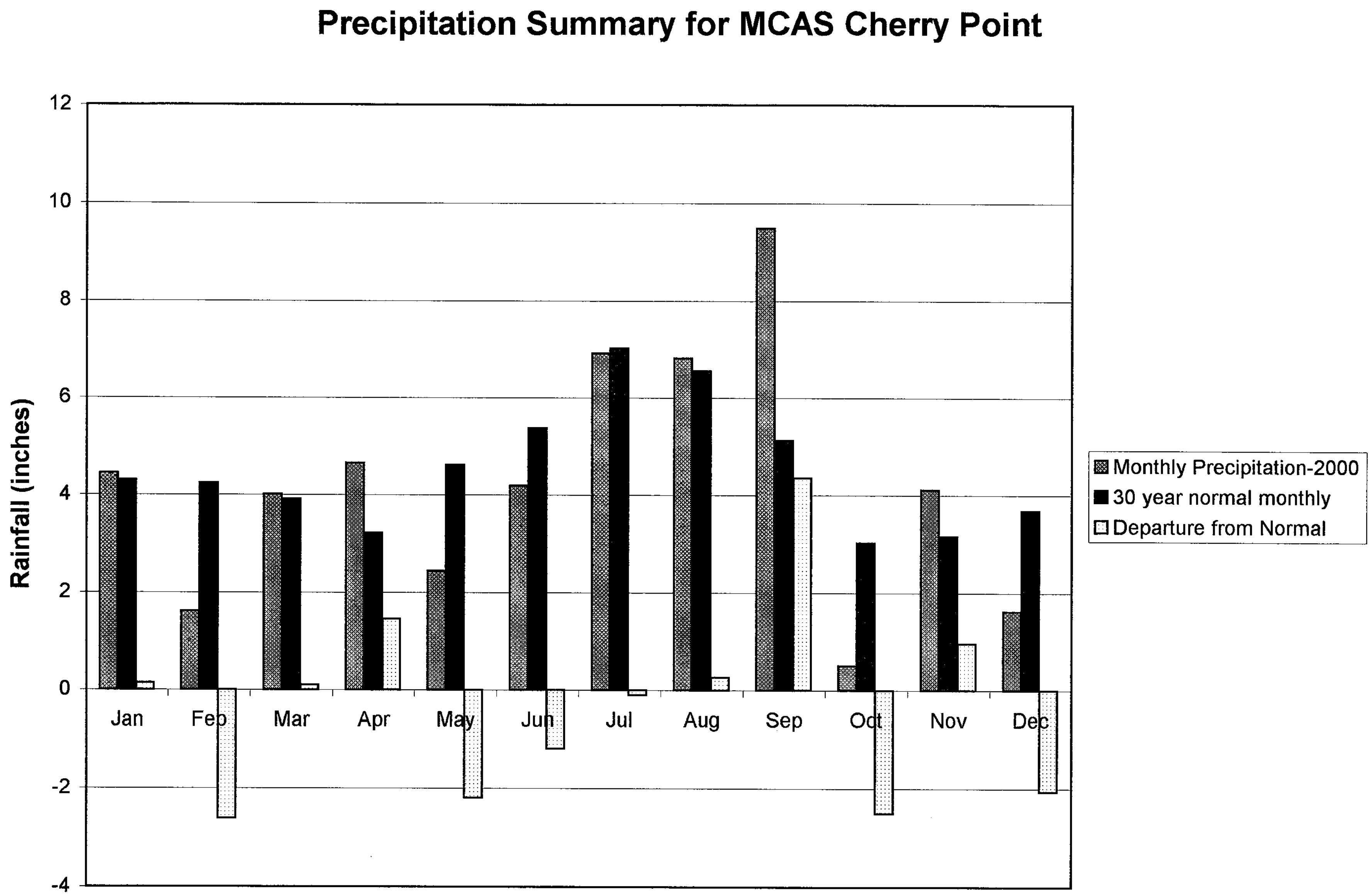

Figure 5. Monthly precipitation totals, 30-year averages, and departure from normal for MCAS Cherry Point, NC in 2000. Departure from normal is the difference between the monthly total for 2000 and the 30-year average. Data were from the USGS Drought Monitoring Program weather station located near the Neuse River on Cherry Point.

Table 25. Water chemistry (pH) values for selected aquatic sampling sites on Cherry Point MCAS in 2000.

	Site								
Month	1	3	4	6	7	8	10	12	13
March	8.21	6.11	5.13	6.26	5.35	4.34	6.42	6.02	4.84
May	7.19	6.31	5.45	5.98	6.24	4.37	6.63	6.09	5.94
June	8.29	5.85	5.67	6.77	5.98	4.76	6.10	5.77	5.55
July	8.83	7.24	5.89	7.89	7.08	5.45	6.17	7.08	5.89
August	7.32	5.98	5.15	6.53	5.21	4.46	5.89	6.03	5.16
October	7.87	6.41	5.57	8.81	5.90	4.86	6.03	5.60	5.65

Table 26. List of amphibian species encountered in the study area on Cherry Point MCAS, Craven County, North Carolina in 1999 and 2000.

Anura (Frogs and Toads)	
Bufonidae:	
Bufo quercicus	Oak Toad
Bufo terrestris	Southern Toad
Hylidae:	
Acris gryllus gryllus	Coastal Plain Cricket Frog
Hyla chrysoscelis	Cope's Gray Treefrog
Hyla cinerea	Green Treefrog
Hyla femoralis	Pine Woods Treefrog
Hyla gratiosa	Barking Treefrog
Hyla squirella	Squirrel Treefrog
Pseudacris crucifer crucifer	Northern Spring Peeper
Pseudacris ocularis	Little Grass Frog
Microhylidae:	
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad
Pelobatidae:	
Scaphiopus holbrookii	Eastern Spadefoot
Ranidae:	
Rana catesbeiana	American Bullfrog
Rana clamitans melanota	Northern Green Frog
Rana sphenocephala utricularia	Southern Leopard Frog
Caudata (Salamanders)	
Ambystomatidae:	
Ambystoma opacum	Marbled Salamander
Amphiumidae:	
Amphiuma means	Two-toed Amphiuma
Plethodontidae:	
Plethodon chlorobryonis	Atlantic Coast Slimy Salamander
Salamandridae:	
Notophthalmus viridescens dorsalis	Broken-striped Newt

Table 27. Number of amphibians captured at Cherry Point MCAS, NC in 2000 by life history stage.

	SEX/ LIFE HISTORY STAGE					
	Male	Female	Juvenile	Larvae	unknown sex	Total
Frogs						
A.gryllus	3	3		19		25
B. terrestris	2	5		2		9
G.carolinensis	9	7	1			17
H. chrysoscelis	14	1		41		56
H. cinerea	66	244	31	3	13	357
H. femoralis	91	17	1	79	1	189
H. gratiosa	14	15		49		78
H. squirella	131	83	21	16	10	261
P. crucifer				52		52
P. ocularis	5			4		9
R. catesbeiana	27	42	16	6	3	94
R. clamitans				2		2
R. sphenocephala	15	9	3	447	2	476
S. holbrookii	46		3			49
Salamanders						
A. means			1		12	13
N. viridescens	11	18		45	1	75
P. chlorobryonis	1	3			1	5
Total	435	447	77	766	43	1767

Table 28. Species occurrence by sampling technique at Cherry Point MCAS in 2000.

	SAMPLING TECHNIQUE					
	Artificial Cover Transects	PVC Pipe Transects	Visual Encounter Surveys	Minnow Trapping	Dip Nets	Frog Call Surveys
Frogs						
A. gryllus			X		X	X
B. quercicus						X
B. terrestris			X	X	X	X
G. carolinensis	X		X	X		X
H. chrysoscelis		X	X	X	X	X
H. cinerea	X	X	X		X	X
H. femoralis		X	X	X	X	X
H. gratiosa			X	X	X	X
H. squirella		X	X	X	X	X
P. crucifer				X	X	X
P. ocularis			X		X	X
R. catesbeiana			X	X	X	X
R. clamitans				X	X	X
R. spenocephala			X	X	X	X
S. holbrookii			X			X
Salamanders						
A. means			X	X		
N. viridescens				X	X	
P. chlorobryonis	X		X			

Table 29. Number of amphibians captured in coverboard transects at Cherry Point MCAS in 2000. Column headings are coverboard transect numbers.

	TRANSECT NUMBER						
	700	800	900	1000	1100	1200	Total
Frogs							
G. carolinensis	1		4		1		6
H. cinerea		1			1	1	3
Salamanders							
P. chlorobryonis			3	1			4
Total	1	1	7		2	1	13

Table 30. Number of amphibians captured in PVC pipe transects at Cherry Point MCAS in 2000. Transect number refers to coverboard transects along which the PVC piles were set (10 per transect).

	TRANSECT NUMBER						
	700	800	900	1000	1100	1200	Total
Frogs							
H. chrysoscelis		1					1
H. cinerea	21	75	23	38	91	100	348
H. femoralis	3	6	3	4	7	12	35
H. squirella	38	82	20	15	9	6	170
Total	62	164	46	57	107	118	554

Table 31. Number of amphibians captured during Visual Encounter Surveys at Cherry Point MCAS in 2000. Site numbers 1 through 16 represent pool and pond numbers and numbers 800, 1000, and 1100 are coverboard transects.

	SITE NUMBER												
	1	3	4	6	7	8	10	14	16	800	1000	1100	Total
Frogs													
A. gryllus			2					2					4
B. terrestris				6								1	7
G. carolinensis			1			4		1				2	8
H. chrysoscelis			12			2							14
H. cinerea					1							1	2
H. femoralis			48	2		3		21				1	75
H. gratiosa			19								1		20
H. squirella	3		15			17						37	72
P. ocularis			1	1				1					3
R. catesbeiana	3		28	14	3				1	1			50
R. sphenocephala		1	2	9	7	1		1					21
S. holbrookii	49												49
Salamanders													
A. means							1						1
P. chlorobryonis	1												1
Total	56	1	128	32	11	27	1	26	1	1	1	42	327

Table 32. Number of amphibians captured in minnow traps at Cherry Point MCAS in 2000. Site numbers 1 through 15 represent pond and pool numbers.

	SITE NUMBER										
	1	4	6	7	8	10	12	13	14	15	Total
Number of trap days at each site:	75	140	64	63	28	35	99	52	42	48	646
Frogs											
B. terrestris	2										2
G. carolinensis	2		1								3
H. chrysoscelis			2								2
H. femoralis		5							2		7
H. gratiosa		37	12								49
H. squirella			1								1
P. crucifer	1										1
R. catesbeiana	4	9	11	3	3	5	4		3	1	43
R. clamitans		1									1
R. sphenocephala	6	88	21	2	31	19	11	19	3		200
Salamanders											
A. means		3		3	1	1	1		1	2	12
N. viridescens	4	16	2			2	2				26
Total	19	159	50	8	35	27	18	19	9	3	347

Table 33. Relative abundance of amphibians and predatory invertebrates in Site 4 at Cherry Point MCAS in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
H. femoralis	0.00	0.00	0.00	0.00	15.63	0.00	0.00	0.00	0.00
H. gratiosa	0.00	0.00	0.00	12.50	0.00	121.43	0.00	0.00	0.00
R. catesbeiana	8.33	5.00	0.00	4.17	0.00	3.57	5.00	0.00	4.17
R. clamitans	4.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	100.00	110.00	95.83	37.50	6.25	0.00	0.00	0.00	16.67
A. means	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00
N. v. dorsalis	12.50	20.00	20.83	4.17	3.13	0.00	5.00	0.00	0.00
Invertebrates									
Crayfish	4.17	10.00	16.67	20.83	34.38	71.43	65.00	32.50	10.42
Odonata larvae	12.50	20.00	16.67	29.17	0.00	3.57	10.00	7.50	6.25
Giant water bug	0.00	0.00	0.00	8.33	0.00	0.00	2.50	0.00	2.08
Pre. Diving beetle	54.17	20.00	4.17	0.00	6.25	82.14	147.50	15.00	10.42
Water scorpion	0.00	0.00	0.00	0.00	0.00	0.00	5.00	2.50	0.00

Table 34. Relative abundance of amphibians and predatory invertebrates in Site 6 at Cherry Point MCAS in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
G. carolinensis	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00
H. chrysoscelis	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00	0.00
H. gratiosa	0.00	0.00	0.00	0.00	0.00	16.67	33.33	60.00	0.00
H. squirella	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	0.00
R. catesbeiana	0.00	0.00	0.00	6.25	8.33	50.00	8.33	20.00	0.00
R. sphenocephala	0.00	0.00	0.00	12.50	50.00	50.00	0.00	40.00	18.75
N. v. dorsalis	0.00	6.25	12.50	0.00	0.00	0.00	0.00	0.00	0.00
Invertebrates									
Crayfish	7.69	18.75	25.00	12.50	41.67	0.00	66.67	50.00	50.00
Odonata larvae	3.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Giant water bug	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00
Pre. Diving beetle	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00

Table 35. Relative abundance of amphibians and predatory invertebrates in Site 10 at Cherry Point MCAS in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
R. catesbeiana	0.00	25.00	0.00	0.00	0.00	0.00	0.00	16.67	10.00
R. sphenocephala	12.50	25.00	162.50	0.00	0.00	25.00	12.50	0.00	0.00
A. means	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
N. v. dorsalis	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Invertebrates									
Crayfish	12.50	12.50	50.00	100.00	225.00	112.50	175.00	141.67	60.00
Odonata larvae	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
Giant water bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00
Pre. Diving beetle	0.00	0.00	12.50	0.00	0.00	12.50	0.00	0.00	0.00

Table 36. Number of amphibians captured in dipnet surveys at Cherry Point MCAS in 2000. Site numbers 1 through 14 represent pond and pool numbers.

	SITE NUMBER									
	1	4	6	7	8	10	12	13	14	Total
Number of sweeps at each site:	75	147	87	66	36	44	110	64	50	679
Frogs										
A. gryllus		11		1		9				21
H. chrysoscelis		38	1							39
H. cinerea		2							1	3
H. femoralis		3	8			2			59	72
H. gratiosa		8	1							9
H. squirella			16			2				18
P. crucifer	12	11		15		10	3			51
P. ocularis									6	6
R. catesbeiana								1		1
R. clamitans	1									1
R. spenocephala	2	32	80	24	75	10	4	7	22	256
Salamanders										
N. viridescens		49								49
Total	15	154	206	40	75	33	7	8	88	526

Table 37. Relative abundance of amphibians and predatory invertebrates in Site 4 at Cherry Point MCAS in 2000 based on the dipnet technique. Values are number of individuals per 50 dipnet sweeps.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
A. gryllus	0.00	0.00	0.00	31.25	0.00	0.00	0.00	0.00
H. chrysoscelis	0.00	0.00	0.00	115.63	3.57	0.00	0.00	0.00
H. cinerea	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00
H. femoralis	0.00	0.00	0.00	9.38	0.00	0.00	0.00	0.00
H. gratiosa	0.00	0.00	0.00	6.25	21.43	0.00	0.00	0.00
P. crucifer	0.00	3.13	35.71	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	25.00	6.25	17.86	0.00	0.00	0.00	0.00	27.14
N. v. dorsalis	8.33	3.13	10.71	62.50	39.29	25.00	5.00	0.00
Invertebrates								
Crayfish	16.67	3.13	0.00	12.50	17.86	70.00	10.00	47.14
Odonata larvae	29.17	3.13	3.57	0.00	35.71	22.50	32.50	2.86
Giant water bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.29
Pre. Diving beetle	25.00	0.00	0.00	0.00	10.71	17.50	2.50	12.86

Table 38. Relative abundance of amphibians and predatory invertebrates in Site 6 at Cherry Point MCAS in 2000 based on the dipnet technique. Values are number of individuals per 50 dipnet sweeps.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
H. chrysoscelis	0.00	0.00	0.00	0.00	3.13	0.00	0.00	0.00
H. femoralis	0.00	0.00	0.00	21.43	0.00	41.67	0.00	0.00
H. gratiosa	0.00	0.00	0.00	0.00	0.00	0.00	4.17	0.00
H. squirella	0.00	0.00	2.78	0.00	0.00	125.00	0.00	0.00
R. sphenocephala	8.33	0.00	13.89	392.86	46.88	0.00	8.33	5.00
Invertebrates								
Crayfish	0.00	0.00	0.00	14.29	3.13	8.33	12.50	45.00
Odonata larvae	0.00	0.00	0.00	7.14	3.13	25.00	0.00	0.00

Table 39. Relative abundance of amphibians and predatory invertebrates in Site 10 at Cherry Point MCAS in 2000 based on the dipnet technique. Values are number of individuals per 50 dipnet sweeps.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
A. gryllus	0.00	0.00	0.00	62.50	8.33	12.50	12.50	0.00
B. terrestris	0.00	0.00	0.00	0.00	0.00	12.50	0.00	0.00
H. femoralis	0.00	0.00	0.00	0.00	8.33	12.50	0.00	0.00
H. squirella	0.00	0.00	0.00	12.50	0.00	12.50	0.00	0.00
P. crucifer	0.00	83.33	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	16.67	25.00	0.00	25.00	16.67	0.00	0.00	12.50
Invertebrates								
Crayfish	33.33	16.67	16.67	50.00	58.33	50.00	43.75	0.00
Odonata larvae	8.33	8.33	0.00	0.00	0.00	12.50	0.00	0.00

Table 40. Amphibian species in each of seven frog call monitoring stations on Cherry Point MCAS in 2000 identified by vocalizations (V). Abbreviations for each species in parentheses are for the following tables.

	Sites						
Species	1	3	4	5	6	10	12
Frogs:							
Acris gryllus gryllus (Agr)		V	V	V	V	V	V
Bufo quercicus (Bqu)	V						
Bufo terrestris (Bte)	V	V		V	V		V
Gastrophryne carolinensis (Gca)	V		V		V	V	V
Hyla chrysoscelis (Hch)	V	V	V	V	V	V	V
Hyla cinerea (Hci)	V	V		V	V	V	
Hyla femoralis (Hfe)			V		V	V	V
Hyla gratiosa (Hgr)			V		V		
Hyla squirella (Hsq)	V	V	V	V	V	V	
Pseudacris crucifer crucifer (Pcr)	V	V	V	V	V	V	V
Pseudacris ocularis (Poc)			V		V	V	V
Rana catesbeiana (Rca)	V	V	V	V	V	V	V
Rana clamitans melanota (Rcl)	V	V					V
Rana sphenocephala utricularia (Rsph)	V	V	V	V	V	V	V
Scaphiopus holbrookii (Shol)	V		V				

Table 41. Seasonal variation in timing of male frog vocalizations at Site 1 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species														
Week of	Agr	Bqu	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp	Sho
February 27										V		V			
March 5										V		V			
March 12										V		V			
March 19										V		V			
March 26										V		V			
April 2						V						V			V
April 9										V		V			V
April 16										V		V		V	
April 23									V					V	V
April 30					V							V		V	V
May 7					V							V			V
May 14												V			
May 21			V	V	V							V		V	V
May 28		V													
June 4												V	V		
June 11												V			
June 18												V		V	V
June 25					V				V						
July 2			V	V	V	V						V			
July 9												V			
July 16															
July 23															
July 30												V			
August 6												V			
August 13															
August 20															
August 27														V	
September 3															
September 10															

Table 42. Seasonal variation in timing of male frog vocalizations at Site 3 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

Week of	Species												
	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp
February 27									V				V
March 5									V		V		V
March 12									V		V		V
March 19	V								V				V
March 26									V		V		V
April 2	V										V		V
April 9	V										V		
April 16	V												
April 23	V										V		
April 30					NO BASE ACCESS THIS WEEK								
May 7	V				V								V
May 14	V				V						V		V
May 21	V			V	V						V		
May 28	V	V			V			V					
June 4	V				V							V	
June 11	V				V								
June 18	V				V						V		
June 25	V				V								
July 2	V	V		V	V						V		
July 9	V										V		
July 16													
July 23	V												
July 30											V		V
August 6	V												
August 13													
August 20													
August 27													
September 3													
September 10													

Table 41. Seasonal variation in timing of male frog vocalizations at Site 1 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species														
Week of	Agr	Bqu	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp	Sho
February 27										V		V			
March 5										V		V			
March 12										V		V			
March 19										V		V			
March 26										V		V			
April 2						V						V			V
April 9										V		V			V
April 16										V		V		V	
April 23									V					V	V
April 30					V							V		V	V
May 7					V							V			V
May 14												V			
May 21			V	V	V							V		V	V
May 28		V													
June 4												V	V		
June 11												V			
June 18												V		V	V
June 25					V				V						
July 2			V	V	V	V						V			
July 9												V			
July 16															
July 23															
July 30												V			
August 6												V			
August 13															
August 20															
August 27														V	
September 3															
September 10															

Table 42. Seasonal variation in timing of male frog vocalizations at Site 3 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

Week of	Species												
	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp
February 27									V				V
March 5									V		V		V
March 12									V		V		V
March 19	V								V				V
March 26									V		V		V
April 2	V										V		V
April 9	V										V		
April 16	V												
April 23	V										V		
April 30					NO BASE ACCESS THIS WEEK								
May 7	V				V								V
May 14	V				V						V		V
May 21	V			V	V						V		
May 28	V	V			V			V					
June 4	V				V							V	
June 11	V				V								
June 18	V				V						V		
June 25	V				V								
July 2	V	V		V	V						V		
July 9	V										V		
July 16													
July 23	V												
July 30											V		V
August 6	V												
August 13													
August 20													
August 27													
September 3													
September 10													

Table 43. Seasonal variation in timing of male frog vocalizations at Site 4 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species														
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Por	Rca	Rcl	Rsp	Sho
February 27									V					V	
March 5									V			V			
March 12									V			V		V	
March 19									V			V		V	
March 26									V			V		V	
April 2									V			V		V	
April 9									V	V		V			
April 16									V		V	V		V	
April 23									V	V		V		V	
April 30	V			V		V	V		V	V		V		V	
May 7	V			V		V	V					V			
May 14	V			V			V					V		V	
May 21	V		V	V		V	V					V		V	V
May 28	V			V		V						V			
June 4	V					V				V		V			
June 11	V			V		V	V			V		V			
June 18				V			V	V				V			
June 25												V			
July 2				V		V	V								
July 9															
July 16															
July 23						V						V			
July 30						V						V			
August 6												V			
August 13												V			
August 20												V			
August 27														V	
September 3															
September 10															

Table 44. Seasonal variation in timing of male frog vocalizations at Site 5 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species												
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp
February 27									V				V
March 5											V		V
March 12											V		V
March 19											V		V
March 26													V
April 2											V		V
April 9		V									V		V
April 16											V		V
April 23											V		V
April 30					V						V		V
May 7					V						V		V
May 14					V								V
May 21		V			V								V
May 28											V		
June 4	V				V						V		
June 11	V	V			V			V			V		V
June 18	V				V						V		
June 25	V	V		V	V						V		
July 2		V			V								
July 9					V								
July 16													
July 23					V								V
July 30											V		
August 6													
August 13													
August 20													
August 27													V
September 3											V		V
September 10													V

Table 45. Seasonal variation in timing of male frog vocalizations at Site 6 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species												
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp
February 27													V
March 5											V		V
March 12											V		V
March 19													V
March 26													V
April 2					V						V		V
April 9		V									V		V
April 16										V			V
April 23								V	V		V		V
April 30	V			V	V	V	V						V
May 7		V		V									V
May 14											V		V
May 21			V					V			V		V
May 28													
June 4	V						V				V		V
June 11								V			V		
June 18				V							V		V
June 25						V		V					
July 2	V	V	V			V	V	V					
July 9													
July 16													
July 23	V		V					V			V		
July 30											V		
August 6	V												
August 13	V							V			V		
August 20													
August 27	V							V		V	V		V
September 3	V												
September 10													

Table 46. Seasonal variation in timing of male frog vocalizations at Site 10 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species												
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp
February 27									V		V		
March 5									V		V		V
March 12									V				V
March 19									V				V
March 26									V				V
April 2													V
April 9													V
April 16									V				V
April 23	V								V				V
April 30	V			V		V		V					V
May 7	V									V			V
May 14													
May 21	V		V			V		V		V			V
May 28	V					V							
June 4	V												
June 11	V												
June 18	V												
June 25	V		V			V		V		V			
July 2	V		V	V	V	V		V		V			
July 9	V									V			
July 16													
July 23	V			V						V			V
July 30	V		V	V	V			V					
August 6	V										V		
August 13	V			V									V
August 20													
August 27	V												V
September 3													
September 10													

Table 47. Seasonal variation in timing of male frog vocalizations at Site 12 on Cherry Point MCAS for 2000. Abbreviations as in Table 40.

	Species												
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pcr	Poc	Rca	Rcl	Rsp
February 27									V				V
March 5									V				V
March 12									V				V
March 19									V				V
March 26									V				V
April 2											V		V
April 9									V				
April 16									V				V
April 23									V		V		V
April 30													
May 7	V										V		
May 14											V		
May 21	V	V	V	V		V					V		V
May 28	V									V			V
June 4	V			V		V							
June 11	V											V	
June 18	V										V	V	
June 25												V	
July 2		V										V	V
July 9													V
July 16													
July 23													
July 30												V	
August 6												V	
August 13											V	V	
August 20													
August 27													
September 3													
September 10													

Table 48. Number of amphibians marked at Cherry Point MCAS in 2000 by life history stage.

	SEX AND LIFE HISTORY STAGE			
	Male	Female	Juvenile	Total
Frogs				
B. terrestris	2	4		6
H. chrysoscelis	14			14
H. cinerea	10	63	5	78
H. femoralis	70	8	1	79
H. gratiosa	12	14		28
H. squirella	64	16	6	86
R. catesbeiana	18	30	12	60
R. sphenocephala	15	6	1	22
S. holbrookii	46			46
Total	251	141	25	417

Table 49. Recapture locations and minimum distances moved for frogs on Cherry Point MCAS in 2000. Sites A and B in coverboard and PVC transects 700 and 800 refer to first and second halves of the transect, respectively.

Species	Location Marked	Location Recaptured	Distance (m)
B. terrestris	pond 4	pond 6	310
H. cinerea	700B	700A (pvc703)	130
H. cinerea	800A	800B (pvc818)	30
H. cinerea	800A	800B (pvc818)	30
H. cinerea	800B	800A (pvc 806)	100
H. gratiosa	pond 12	road adj. to 1200A	90
H. squirella	800B	800A (pvc809)	70
R. sphenocephala	pond 4	pond 14	220

RESULTS FOR MARINE CORPS BASE CAMP LEJEUNE

INTRODUCTION

Marine Corps Base Camp Lejeune is located in Onslow County, North Carolina (**Figure 1**). It was established in 1941 and named in honor of LtGen John A. Lejeune. Camp Lejeune is home to the II Marine Expeditionary Force and the U.S. Marine Corps Forces Atlantic. The installation is comprised of approximately 153,000 acres of land that is divided into two subequal parts by the New River. The base has 22 kilometers of marine shoreline used for military training, swimming, and fishing. Parts of the beach are managed for two species of federally endangered sea turtles because they nest there on an annual basis. Before 1941, the land was in private ownership and in poor condition due to over-harvesting of forests and extensive agriculture. The first natural resources management plan was prepared in 1946. Natural re-growth of vegetation and forest management since that time has established Camp Lejeune as an important center for regional biodiversity. A variety of rare or unusual natural communities occur on the installation (LeBlond et al., 1994).

Amphibian species richness expected for MCB Camp Lejeune and vicinity is based on species distribution maps in Conant and Collins (1998) and include 22 species of frogs and toads and 14 species salamanders. In the two years we have been working in the specific study area we have encountered 17 species of frogs and 6 species of salamanders, or 63% of the expected amphibian fauna for the region (77% of frogs, 43% of salamanders). We used six standardized techniques to monitor amphibians in our study area on MCB Camp Lejeune. This report summarizes the results from the six techniques used in 1999 and 2000. This report summarizes the results for 2000. Results from the monitoring project conducted in the field season of 1999 are in Mitchell (2000).

The objectives of the fieldwork in 2000 (largely FY 00) were primarily to expand the baseline data on amphibian occurrence and relative abundance obtained in 1999, and to evaluate seasonal changes in amphibian activity at selected sites. These complimented the overall project objectives.

Early in the 2000 field season my field crew and I encountered a case of fungal disease in one species of frog on Camp Lejeune. This report summarizes the results of this unexpected aspect of our survey.

STUDY SITE DESCRIPTIONS

Study Area and Habitat

The study area for our amphibian monitoring project in 1999 and 2000 was located in Training Areas HD and HH in the vicinity of LZ Jaybird (**Figure 6**). The area is characterized by sandy soil and a variety of natural isolated wetlands called limesinks surrounded by a mixed pine and hardwood forest. The forest in this area was heavily impacted by Hurricane Fran and was significantly altered. This storm and the salvage operation opened the canopy and resulted in a flourish of understory growth of woody vegetation. Portions of this area contain lots of downed woody debris.

The dominant habitat type in mainland Onslow County, North Carolina, is mixed hardwood and pine forest. An unknown portion of the county was originally in longleaf pine and wiregrass habitat, including a portion of our study area. Total wetland area in the county is 77,701 ha, whereas non-wetland area is comprised of 118,106 ha (195,807 ha total land area). The habitat on MCB Camp Lejeune is currently mostly upland pine flatwoods with patches of mixed hardwoods and riparian systems along creeks with characteristic vegetation. Some of the installation near the primary study area is managed specifically for longleaf pine and federally endangered red-cockaded woodpeckers.

Precipitation Summary for 2000

For most months of 2000, Camp Lejeune received less than normal precipitation (**Figure 7**). Only in the months of April, July, September, and November was there normal or greater than normal rainfall in the area. Total rainfall for April was substantially higher than normal and it was the only month during the January – June period in which rainfall exceeded the previous 30-year normal levels. The low precipitation in May caused several of the isolated wetlands to dry up. The precipitation that occurred in September was from hurricane activity that did not results in local damage. Precipitation in October and December was, like earlier in the year, below normal. The result was that most of the isolated wetlands in our study area held water through the winter of 2000-2001.

Terrestrial Habitat Descriptions

Artificial coverboard transects were established in forested areas near and around study ponds to gather data on inter-pond movements of amphibians and on populations of amphibians that are largely or wholly terrestrial in habits. Vegetation analysis of these areas revealed few significant differences between the six established transects (Mitchell, 2000), hence the following descriptions apply to all of them. Results of the plant ecology evaluation along the transects were summarized in Mitchell (2000) and are included here in abbreviated form without the supporting documentation.

The overstory vegetation for all transects is dominated by loblolly pine (*Pinus taeda*) with smaller numbers of sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). Other overstory trees include red bay (*Persia borbonica*), flowering dogwood (*Cornus florida*), and several species of oaks (*Quercus* spp.). Understory vegetation shows slightly more evenness in dominance between sweetgum and red bay. A large number of forbs occur at the sites, the most abundant being several species of thoroughwort (*Eupatorium* spp.) and partridgeberry (*Mitchella repens*). Controlled burns were carried out in the forest near transects A and C during the winter of 1999-2000.

Aquatic Habitat Descriptions

With a few exceptions, most of the natural pools (limesinks) and manmade pools in our study area have generally similar physical and vegetational characteristics. Ponds with such similarities are grouped together under the appropriate descriptions given here. All of these pools dried up in the summer of 1999 and several of them dried during May 2000. Acidity levels are variable among these isolated wetlands on both seasonal and landscape levels (**Table 50**). Madmade pools like site 18 tend to be neutral to basic, whereas natural limesinks like site 23 tend to be acidic.

Pools 1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 25, 26, 32 - These pools, locally called limesinks, are all relatively small, most nearly circular in shape, and occur primarily in the southeastern corner of our study area, between the open LZ Jaybird training area and the access road leading to the study area from highway 172. These ponds are all shallow (< 1m) and contain little emergent vegetation. Most have a number of logs and tree snags present. The substrate is mainly clay. The surrounding forest is a mix of loblolly pine (*Pinus taeda*) and various hardwoods (see descriptions for artificial cover transects below). All of these pools dried up during the summer of 1999 and refilled in September 1999 due to heavy rains associated with hurricanes Dennis and Floyd. Some retained water through 2000. Most of these pools are acidic (**Table 50**).

Pools 13, 14, 15, 16, 17, 18, 19, 30, 31 - These pools are located in the open gunnary emplacement in the southwestern side of the study area. They feature a somewhat variable and moderate amount of emergent vegetation. Pond 16 has a conspicuous growth of water lilies. Most of the emergent vegetation, however, consists of various grasses. The substrate in these ponds is mainly clay. The amount of organic matter in the substrate varies from moderate in Pond 16 to very little in Pond 14. Various successional grasses, forbs, short scrub oaks (*Quercus marilandica*) and young loblolly pines (*Pinus taeda*) dominate the surrounding vegetation. This group of pools has been heavily impacted by human activities. Wheel ruts and tank tracks are present throughout the site, some passing through the ponds themselves. Most of the ponds contained water throughout 2000. These pools are generally neutral to basic in water chemistry (**Table 50**).

Pools 3, 4 - These pools are located just to the southwest of the access road the LZ Jaybird training area. They are shallow (< 1m) with an abundance of grasses and occur over a broad area. Some emergent vegetation occurred throughout the ponds' surface. Both pools contained water throughout the sampling period but water levels were very low during May. Acidity levels in these pools tend to be nearly neutral (**Table 50**).

Pool 23 - At approximately 210m x 160m in area, this isolated wetland is the largest in the study area. It is shallow, with only a small area being ~ 1.5 m in depth or greater. The abundant emergent vegetation consists of grasses and water lilies. Numerous logs and tree snags occur around the pond's periphery. The substrate is highly organic in content. Vegetation around the edges of this pond includes alder (*Alnus serrulata*), wax myrtle (*Myrica cerifera*), and loblolly pine (*Pinus taeda*). This pond dried up during the summer of 1999 and refilled from heavy rains caused by hurricanes Dennis and Floyd in September 1999. It has not dried out since that time. This limesink may be one of the most important isolated wetlands in the area because it supports large populations of several species of amphibians, including a state threatened species (LeBlond et al., 1994). This wetland was one of the most acidic pools in the study area in 2000 with pH levels ranging from 4.66 to 5.18 (**Table 50**).

Pool 24 - This isolated wetland lies to the north-northeast of the access road leading to the New River. It is approximately 150m x 60m in size. This pond is similar to Pond 23 in emergent vegetation and substrate properties. It contained water throughout the 1999 sampling period, as well as throughout 2000. It also contains a state listed amphibian (LeBlond et al., 1994), however, it is considerably less acidic than Site 23 (**Table 50**).

Pool 29 - This linear pool lies adjacent to the access road leading from highway 172 to the study area. It is heavily vegetated, with emergent grasses and a stand of cattails (*Typha* sp.). It may have been formed as a result of construction activities along the adjacent road. It dried up during the summer of 1999.

Pools 27 and 28. These two pools are located at the western edge of the study area adjacent to the western margin of the gunnery emplacement. They are shallow, have little vegetation of any kind, contain an abundance of snags, and have clay-based substrates. Mixed hardwoods and pines surround both pools. They contained water throughout most of 2000. Acid levels are near neutral to slightly basic (**Table 50**).

RESULTS

<u>Amphibian monitoring protocols</u>

During the first two years of research in on MCB Camp Lejeune, we have observed or captured 17 species of frogs and 6 species of salamanders (**Table 51**). In 2000, we captured 14 species of frogs and four species of salamanders in our study area. We captured a total of 4,984 individuals as larvae, juveniles, or adult males or females (**Table 52**). We obtained over 1,000 individuals of the American bullfrog (*Rana catesbeiana*) and southern leopard frog (*Rana sphenocephala*). These two species accounted for 67% of all frogs captured. Other species of frogs captured in large numbers were southern cricket frogs (*Acris gryllus*), Cope's gray treefrog (*Hyla chrysoscelis*), barking treefrogs (*Hyla gratiosa*), and squirrel treefrogs (*Hyla squirella*).

Most cricket frogs and treefrogs were captured as adults, whereas many of the other abundant species were captured as tadpoles. The broken-striped newt (*Notophthalmus viridescens*) was the most abundant salamander captured in 1999 and 2000.

Most frogs were captured during the execution of four of the six standardized monitoring protocols we used at MCB Camp Lejeune (**Table 53)** but all techniques yielded frogs. Little grass frogs (*Pseudacris ocularis*) were captured only with two techniques (coverboards and frog call surveys, respectively). All other species were captured by three or more techniques. The frog call survey method was the only one that recorded all of the frog species present in the area in 2000. Broken-striped newts (*N. viridescens*) and the lesser siren (*Siren intermedia*) were captured by the two aquatic techniques. Mabee's salamander (*Ambystoma mabeei*) was found with aquatic and visual encounter survey methods. The Atlantic Coast slimy salamanders (*P. chlorobryonis*) were captured only by the artificial coverboard technique.

Artificial coverboard transects yielded a total of 26 individuals of six species of frogs and 11 individuals of one species of salamander (**Table 54**). The frogs and salamanders were distributed randomly among the transect sites. The low number of captures of amphibians was three times higher than the number caught in 1999. This technique is not appropriate for monitoring amphibians in this area, although it was the only method to yield slimy salamanders. The largely terrestrial narrow-mouthed toad (*Gastrophryne carolinensis*) was captured in substantially larger numbers than the other species of frogs.

PVC pipe refugia along transects have proven to be a useful monitoring technique for at least two species of treefrogs at MCB Camp Lejeune. A total of 301 adult individuals of six species of treefrogs was captured in 2000 (**Table 55**). Of these, 75% were squirrel treefrogs (*Hyla squirella*) and 21% were pine woods treefrogs (*Hyla femoralis*). The number of green treefrogs (*Hyla cinerea*) captured in 2000 was substantially lower than in 1999 (Mitchell, 2000). Other species captured can be considered incidental. All PVC pipes on all transects yielded treefrogs, suggesting that at least the two most common treefrogs are distributed throughout the terrestrial habitat in the area.

A total of 318 amphibians were observed or caught during visual encounter surveys in the study area (**Table 56**). Five species were observed more commonly than the others in both 1999 and 2000, southern cricket frog (*A. gryllus*), barking treefrog (*H. gratiosa*), squirrel treefrog (*H. squirella*), bullfrogs (*R. catesbeiana*), and southern leopard frogs (*R. sphenocephala*). Number of species observed with this technique varied from one at wetland sites 29, 30, and 32 to six at site 23. Nearly all sites we studied supported amphibians.

The minnow trap technique was highly successful at 22 isolated wetland sites on MCB Camp Lejeune. Total number of frogs captured was 2,120 and the total number of salamanders captured was 114 (**Table 57**). Numbers of captures for individual species varied from one for two species (pine woods treefrog, *Hyla femoralis*, ornate chorus frog, *Pseudacris ornata*) to 1,076 (bullfrog, *Rana catesbeiana*). Most of the latter were tadpoles. Three species of salamanders were caught in minnow traps in 2000, compared to one species in 1999. Broken-striped newts (*Notophthalmus viridescens*) were captured in 11 of the isolated wetlands, whereas Mabee's salamanders (*Ambystoma mabeei*) were caught at two sites and lesser sirens (*Siren intermedia*) at one site. Number of individual amphibians captured among isolated wetlands varied from 3 in site 30 to 560 in site 23. Number of species captured in the isolated wetlands varied from 1 in sites 4 and 30 to 7 in sites 23 and 24.

Relative abundance of amphibians and the suite of their invertebrate predators varied dramatically among examples of three limesinks in our study area and among months (**Tables 58-60**). Invertebrate predators and predator groups included crayfish (*Procambarus acutus*), odonate larvae (dragonfly and damselfly nymphs), giant water bugs (*Lethocerus americanus*), predaceous diving beetles (*Cybister fimbriolatus*), and water scorpions (*Ranatra* spp.). Amphibians and their predators were abundant in Site 1 during February through May but were absent in June and July because the pool dried up (**Table 58**). Both the amphibians and their predators recolonized the pool following rains in August. The amphibian community was dominated by cricket frogs (*Acris gryllus*) and ranid frog (*Rana* spp.) tadpoles throughout 2000 in site 15, although the variation in relative abundance was dramatic (**Table 59**). Two species of invertebrate predators were present in this pool but their relative abundance was high in most months, especially for crayfish. In Site 23, the largest isolated wetland in our study area, the amphibian community was highly diverse and variable over time, and consisted of 7 species (**Table 60**). The corresponding invertebrate community was also diverse with 5 species and species groups. Relative abundances varied dramatically among months for amphibians and the invertebrates. Relative abundance of predators was high compared to that for amphibian larvae, especially for crayfish. Only in March and April were tadpoles relatively abundant and most of these were dominated by one species, the southern leopard frog (*Rana sphenocephala*).

Invertebrate predators were abundant in this wetland even when amphibian larvae were not (e.g., May-June, September-October). The large numbers of invertebrate predators in these isolated wetlands suggest that they play important roles in regulating aquatic amphibian populations and communities.

Dipnet surveys were conducted in 19 of the isolated wetland sites in our study area on Camp Lejeune. A total of 1,460 individuals of six species of frogs and 230 individuals of three salamander species was captured in 2000 (**Table 61**), compared to 977 frogs and 28 salamanders in 1999. Captures of frogs were dominated by southern leopard frog (*Rana sphenocephala*) tadpoles (35%), bullfrog (*Rana catesbeiana*) tadpoles (20%), southern cricket frog (*Acris crepitans*) tadpoles (10.7)%), Cope's gray treefrog (*Hyla chrysoscelis*) tadpoles (12.7%), and barking treefrog (*Hyla gratiosa*) tadpoles (7.2%). Number of species obtained by the dipnet survey technique varied from one in site 11 to 9 in site 32. Number of individual tadpoles obtained in dipnet sweeps varied from 12 in site 4 to 284 in site 23. Broken-striped newts (*Notophthalmus viridescens dorsalis*) and their larvae were relatively common in these isolated wetlands, occurring in 14 sites. Mabee's salamander (*Ambystoma mabeei*) was found in only one wetland with this technique (32) and lesser siren (*Siren intermedia*) was found in two sites (11 and 12). Numbers of salamanders were dominated by newts, ranging from 1 in sites 16, 17, 27, and 28 to 76 in site 23.

Relative abundance of amphibians and their invertebrate predators obtained in dipnet sweeps varied among wetlands and across time but mirrored the results obtained with the minnow trap technique (**Tables 62-64**). Species richness of amphibians and predators obtained by minnow traps and dipnets were similar in Site 1 but dipnets revealed more treefrog tadpoles in August and September (**Table 62**). Dragonfly and damselfly nymphs dominated the invertebrate community. Dipnets used in Site 15 revealed all but one species captured by minnow traps but dipnets captured more species of invertebrate predators (**Table 63**). Bullfrog tadpoles were the most abundant species in the amphibian community in all months, whereas crayfish dominated the invertebrate community. In Site 23, dipnet sweeps captured the same suite of amphibian and predator species and they obtained similar relative abundances as that obtained by minnow traps (**Table 64**). Southern leopard frog tadpoles and adult and larval newts dominated amphibian samples in most months. Crayfish, odonate larvae, and predaceous diving beetles were abundant in all months in this limesink. These comparisons support the conclusion made for the minnow trap results that these invertebrate predators play important roles in these isolated wetlands.

The weekly nighttime frog call survey of 8 of the isolated wetlands on Camp Lejeune yielded information on all 14 of the 15 species of frogs documented to date (**Table 65**). This commonly-used monitoring technique is based on male vocalizations. This technique recorded 6 to 12 species in these eight wetlands in the 2000 field season, compared to 4-10 species in 1999 (Mitchell, 2000). Twelve species called at sites 12 and 24, 10-11 species called at sites 1, 3, and 23, 9 species called at site 18, and 6 species called at site 29. Most of the sites monitored supported the majority of frog species found in the study area. **Tables 66-72** illustrate the seasonal occurrence of the 14 species of frogs that occurred in 2000 in each of the eight isolated wetlands we studied. There was considerable variation in seasonal timing of male vocalizations in each wetland. For example, southern cricket frogs (*Acris gryllus*) called extensively in 7 of the 8 isolated wetlands in 2000, compared to 5 of the study sites in 1999 (Mitchell, 2000). Many species called for several weeks in a row, then skipped one or more weeks before calling again (e.g., Cope's gray teefrog [*H. chrysoscelis*], pine woods treefrog [*H. femoralis*], and southern leopard frog [*R. sphenocephala*]). Southern cricket frogs, barking treefrogs, bullfrogs, and southern leopard frogs called for many weeks, often consecutively, in the study area in 2000. This is probably in response to the greater amount of precipitation in 2000 compared to 1999. Based on calling males alone, the frog fauna of Camp Lejeune appeared to be dominated by six species in 2000: southern cricket frogs, Cope's gray treefrog, pinewoods treefrog, barking treefrogs (*H. gratiosa*), spring peepers (*P. crucifer*), bullfrogs (*R. catesbeiana*), and southern leopard frogs.

We marked a total of 355 frogs in 2000 on Camp Lejeune (**Table 73**), compared to a total of 212 frogs 1999 (Mitchell, 2000). The following species were marked by toe clipping in 2000: southern toads (*Bufo terrestris*), Cope’s gray treefrog (*Hyla chrysoscelis*), green treefrog (*Hyla cinerea*), pinewoods treefrogs (*Hyla femoralis*), barking treefrog (*Hyla gratiosa*), squirrel treefrogs (*Hyla squirella*), bullfrogs (*Rana catesbeiana*), and southern leopard frogs (*Rana sphenocephala*). Most of the treefrogs, especially squirrel treefrogs, were captured during visual encounter surveys at night. The total of 567 marked frogs served as the basis for our preliminary movement results.

We were able to recapture 6 individual frogs in 2000 that we had marked previously (**Table 74**). All recaptures but one were treefrogs that had moved from one end of a coverboard and PVC transect to the other. Minimal distances moved ranged from 70 to 130 meters. The only non-treefrog captured was a bullfrog that had moved from manmade depressional pools from Site 14 to Site 13, minimally 40 meters away. We are confident that we will obtain substantially more recaptures in 2001.

Amphibian disease survey

On 2 February 2000 my field crew and I found a dead adult southern leopard frog (*Rana sphenocephala*) in Site 23 on Camp Lejeune. We sent it to Dr. David E. Green, a leading amphibian pathologist at the National Wildlife Health Center (NWHC) in Madison, Wisconsin, for evaluation. We knew that dead and dying amphibians had been found in other parts of the United States and some of those animals had contained a potentially serious disease. Dr. Green performed virology, parasitology, bacteriology, and histopathology studies on this specimen. Several nematodes were found in the body cavity and two species of bacteria were detected. Histopathological preparations revealed the presence of vacuoles of *Batrachochytrium dendrobatidis*, a fungal organism (a chytrid fungus) known to kill amphibians in other parts of the world. The disease is called chytridiomycosis.

On Dr. Green's advise we collected 6 live recently-metamorphosed southern leopard frogs from Site 23 and one other site (Site 27) in mid-May 2000. We sent them to the NWHC for evaluation to determine if the disease could be confirmed. Histopathology revealed that 2 of the metamorphs contained chytrid fungus infections. One was from Site 23 and one was from Site 27. The infections were considered mild but would have likely killed the infected animals in 2-4 weeks (D.E. Green, personal commnication). The possibility exists, therefore, that this disease organism could cause a serious decline of the leopard frog population in this area. However, many question remain as to whether this disease occurs naturally in eastern North Carolina, whether it actually causes serious population declines in this area, whether declines (if they occur) are cyclical, and whether the fungus is more widespread than in the immediate study area. Our observations and research on Camp Lejeune revealed that the southern leopard frog population apparently remained large during 2000 (see numerical results above). Results of our work in 2001 (FY 01 contract year) will shed additional information on whether this species has declined in abundance.

I also sent Dr. Green one adult barking treefrog (*Hyla gratiosa*) that initially appeared to have a parasite under its skin on the belly. His necropsy revealed that the lump was actually an umbilical hernia of the intestines and is likely a congenital malformation. Although it had a nematode parasite infection in its body cavity, it contained no evidence of the chytrid fungus. This observation leads to the suggestion that arboreal frogs may not easily pick up the fungal disease. Although barking treefrogs are arboreal during warm months, they overwinter underground at unknown distances from their breeding ponds. Since the chytrid fungus is picked up by frogs in aquatic environments, it is likely that barking treefrogs may not be very susceptible to this disease. Additionally, the skin of treefrogs is structurally different from leopard frogs and may differ in its abilities to be infected (D.E. Green, personal communication). Thus, it is likely that the chytrid fungus may be a problem for frogs that remain in water for extended periods of time and less so for treefrogs and more terrestrial frogs (e.g., southern toads).

DISCUSSION AND CONCLUSIONS

Amphibian monitoring

The frog fauna we encountered in 2000 in our study area on Camp Lejeune consisted primarily of species that use shallow, ephemeral bodies of water or limesinks for breeding. These isolated wetlands are characterized by highly variable hydrologies with some pools retaining water for a year or more and others that hold water only for several months. Species of amphibians that use these pools are those that are adapted to these variable hyrdologies. All of the frog species in this area use the surrounding forested habitat for shelter during most of the year except for times of mating and egg laying. Thus, both these isolated wetlands and the surrounding terrestrial habitats are essential to the long term survival of these sensitive species on Camp Lejeune. Management of the forest on the installation that results in elimination of terrestrial refugia may impact amphibian populations. Most treefrogs use arboreal refugia (trees) extensively, whereas several species of frogs and most of the salamanders use terrestrial and subterranean microhabitats exclusively. The state threatened Carolina gopher frog (*Rana capito*) uses underground retreats for much of the year. These arboreal and underground refugia are located at varying distances from the isolated wetland breeding sites. Unfortunately, we lack detailed information on the distances these animals move from these wetlands. However, research done so far suggests that upland refugia are located as far as 165 meters or more away and that some individuals move great distances (Semlitsch, 1998, 2000; Semlitsch and Bodie, 1998). If protection and management of amphibians is an important resource management goal, then amphibian ecology and dynamics in aquatic and terrestrial habitats must be considered in development of management plans involving forestry, wildlife, landscape, or military training operations. The areas around isolated wetlands should be targeted for management with amphibian populations in mind, and a minimal buffer distance should be in the neighborhood of 165 meters. Because areas such as that included in our study on Camp Lejeune include a number of isolated wetlands (limesinks), then the entire area should be managed at the landscape level, rather than by single wetland units.

The use of multiple standardized techniques provides a more complete picture of the amphibian fauna in an area than one technique used alone. Results of monitoring studies such as this one are dependent on the methods used. Coverboards may not be a useful technique for amphibians, although they are useful for reptiles. PVC pipe refugia are a good way to monitor treefrogs in terrestrial habitats as long as one can identify individuals so that counting the same animal is avoided. The visual encounter survey is a very important tool to obtain a wide variety of information on the status of amphibian populations and especially useful for assessment of diseased or malformed frogs. This technique, however, must be done by experienced individuals who know how to "read" the observations they make and who know when to capitalize on opportunities when they arise (e.g., what to do with dead and dying frogs). The best technique for monitoring presence and absence, as well as seasonal phenology, of frogs is the frog call survey. However, this method will not tell you whether each species reproduces in each wetland. This technique is best coupled with either the dipnet or minnow trap technique, or both, used to assess the aquatic fauna. Many researchers have not used these techniques because of the difficulties with tadpole and salamander identification. However, these combined techniques, as we have done in this study, yield the best picture of the status of amphibian communities and populations at several scales, annual, seasonal, and landscape.

The results of the first two years of study suggest that detailed information on the frog fauna can yield useful information on how amphibians use the landscape. Thus, this information will be useful to resource managers when developing management plans that involve protection and restoration of natural habitats. The diversity of the sinkhole pond wetlands and other ephemeral wetland habitats in the area supports a rich suite of species characteristic of the region. Species richness is high in this area despite the surface effects of silvicultural operations that have created clearcuts, shelterwood cuts, and moncultures and natural disturbances, such as wind throw from hurricanes. The potential for natural habitat restoration is high. However, it would be wise to understand the terrestrial dynamics of these animals before serious on-the-ground changes are made.

The amphibians in this area undoubtedly disperse long distances away from wetland breeding sites like many species do in other types of habitats (see reviews in Dodd, 1996; Semlitsch, 1998; Pauley et al. 2000). Knowledge of movement distances, coupled with information on the habitats used for each life history stage, will provide resource managers with the tools to more completely understand how amphibians use the landscape. The key species for which this information is needed is the Carolina gopher frog, but similar information on other species would be instructive on how to approach management at the landscape level. Such information can be used to formulate management objectives and direct land use operations in the area.

Amphibian disease

The chytrid fungus is considered by pathologists to be a major cause of amphibian decline and species extinction in many parts of the world (Berger et al., 1998; Longcore et al., 1999; Morell, 1999; Carey, 2000; Daszak et al., 2000). It has caused extinctions of frogs in Australia and Central America (Daszak et al., 1999). Indeed, infectious diseases that affect wildlife and potentially humans are a growing health concern (Daszak et al., 2000). Recent extensive media reports of mad cow disease and hoof and mouth disease in domestic livestock have heightened the concern over the potential health and economic risks of infectious diseases. There is no evidence that chytridiomycosis could infect humans. It is not likely because diseases of amphibians, an ectotherm (cold-bloodied animal), do not usually transfer to endothermic animals (e.g., warm-bloodied mammals). The primary concern with chytridiomycosis is the potential for population decline and extinction of species, as has already been documented for the tropics and western United States (Daszak et al., 1999). Such declines and loss of species could have serious ecological and natural resource consequences at the local level (e.g., installation).

Because the chytrid fungus is now known to occur on Camp Lejeune, the monitoring and survey work we have been doing there and on other installations has an added dimension. The problem is a wildlife issue and an ecosystem issue. Southern leopard frogs and other species that may be susceptible to this fungal disease are prey for a large number of terrestrial and semi-aquatic predators (e.g., snakes, wading birds). The larval stages, the tadpoles, are primary consumers that eat algae and other plant matter. Tadpole populations regulate the energy dynamics of aquatic ecosystems, like those in limesinks, and serve as important prey for many invertebrates that are themselves prey for other animals. Loss of these ecologically important animals will have a dramatic cascading effect in places like Camp Lejeune. Natural ecosystem function is likely to be altered substantially, although the actual effects cannot be predicted. Thus, the most important things we can do at this time are to (1) be aware of the problem and realize that it could be widespread, (2) continue monitoring and surveying amphibian populations on military installations in the East and Southeast, (3) determine whether the disease is more widespread than the immediate study area on Camp Lejeune, and (4) determine if the disease occurs elsewhere in the eastern United States. The work we will be doing in Year 3 of this project (FY 02 funding) will allow us to expand our survey on Camp Lejeune and to begin an initial survey of amphibians for the presence of this disease on Fort Stewart, Georgia. Results of this work will be summarized in the final report for year 3.

My field crew and I have not seen serious malformations of amphibians on any of the installations we have been working. We have not observed the high incidence levels reported for the upper Midwest and parts of the West (Helgen et al., 1998; Meteyer et al., 2000) that gained widespread media attention in recent years. Malformations have not been observed thus far in our surveys in eastern North Carolina. Additional survey work is urgently needed to determine if malformations are occurring on these and other installations.

Conclusions

The following conclusions can be drawn from the results of the first two year's of research on the amphibians of MCB Camp Lejeune.

1. The mixed pine and hardwood forest and the associated clusters of isolated wetlands (limesinks) characteristic of our study area on Camp Lejeune support a rich diversity of amphibians.

2. A combination of standardized monitoring and capture techniques is required to encounter the entire amphibian fauna. No one technique is useful to monitor all life history stages of all species.

3. The weekly nighttime frog call survey is the best technique to assess the presence or absence of a frog species at isolated wetland sites, although it can say little about its reproductive use or success in a specific habitat or site.

4. Determining whether a particular wetland is used for reproduction requires the use of the dipnet and minnow trap techniques, as well as visual observation.

5. The amphibian fauna at Camp Lejeune is dynamic, and species are active on different seasonal cycles. Monitoring of all species requires multiple techniques used over the entire season, including winter, to obtain information on all species present.

6. Preliminary information on distances moved by frogs in our study area on Camp Lejeune has yielded few insights so far. The fieldwork conducted in 2001 should yield additional captures and provide information on distances moved by amphibians between wetlands and between wetlands and terrestrial locations.

7. Populations of amphibians are regulated by a variety of factors, environmental and biological. Understanding the dynamics of amphibian populations and communities requires information on environmental parameters and data on predators and prey resources. Future work on such factors on this installation, combined with the existing baseline data on amphibian populations, will yield insights into population and community dynamics over time and among habitats.

8. The confirmed presence of the chytrid fungus in southern leopard frogs at Camp Lejeune was an unexpected result of our fieldwork. At this point, amphibian populations do not appear to be declining, although we have been studying this area for only two years so far. Because the potential exists for population decline, we should monitor the amphibians in this area for several more years. In addition, we should expand our search to include other species and other isolated wetlands. Is this disease widespread on Camp Lejeune and what are its effects?

9. Malformed amphibians have not been found on Camp Lejeune. However, continued fieldwork in our primary study area and in other locations should reveal cases of this problem if it is occurring.

PRELIMINARY MANAGEMENT RECOMMENDATIONS

1. If the primary management goal for amphibians is to maintain the current level of species richness and at viable population sizes, then the diversity of terrestrial and wetland habitats should be maintained.

2. Because only one state threatened species occurs on Camp Lejeune (Carolina gopher frog), additional research should be conducted on this species. In particular we need information on its distribution on the installation, its seasonal dynamics, population size, terrestrial non-breeding locations, distances they move from their wetland breeding sites, and all aspects of its life history.

3. Other amphibian species should be managed as communities and not as single species. Focus on habitat management. Although some species appear to be rarely encountered, they should not yet be considered rare and specifically managed to enhance their population. Single species management may not be the best approach with the majority of the amphibian fauna in this area.

4. Monitoring of the amphibian fauna is likely to reveal habitat distribution and population dynamic patterns that will be useful to resource managers. Because patterns change with habitat

change and over time, monitoring of this fauna should be considered a long-term effort. The three-year baseline data set obtained in this study will provide the basis for evaluation of changes in the future. Funding should be targeted for continuation of monitoring programs after the Legacy Resource Management Program support has ended.

5. Ecotoxicology studies of effects of herbicides and pesticides on amphibians have not been thorough and often use only a laboratory species not found in North America (McDiarmid and Mitchell, 2000). Spraying herbicides and pesticides in and over terrestrial and wetland habitats could produce harmful results for amphibians, especially at the larval stage. Decisions to use chemicals in this are should be made with extreme caution.

6. The natural hydroperiod of the area should be maintained to the extent possible. The amphibians in this area have long been adapted to the natural hydrological fluctuations. Activities such as ditching and clearcutting that results in increased evaporation should be avoided when and where possible.

7. The introduction of non-native and invasive species of plants and animals should be resisted. This could include North American "native" species found outside of eastern North Carolina that could be harmful to amphibians.

8. Captive-raised or captive-bred amphibians should not be released in this area under any circumstances. The potential for disease introduction is growing and every effort should be made to avoid contamination from exotics or native species from other areas. Captivity often induces stress and influences development of disease.

9. It would be advisable to review existing management activities that affect the habitat and hydrology of the area with management of amphibian communities and populations in mind. Such reviews may reveal conflicts that could be avoided or mediated if detected before problem arise.

10. It would also be advisable to review the myriad of wildlife management programs that are being used on Camp Lejeune to identify activities that may be in conflict with management activities that focus on amphibians.

11. Because the chytrid fungus has been confirmed on Camp Lejeune and because it has the potential to cause severe population decline of some species of amphibians, widespread searches for diseased animals should be supported. In addition, monitoring of amphibian populations should be a long-term effort and supported financially. The baseline data are in place to evaluate population and community changes but detection of change requires that monitoring with standardized techniques be a long-term effort. Knowing where the disease occurs, which species are infected, and whether populations are affected is the first step in management of this potential natural resource problem.

12. A recent review of declines in reptiles (Gibbons et al., 2000) shows conclusively that reptile populations in many areas have declined even more dramatically than amphibians. It would be advisable for resource managers on Camp Lejeune and other installations to initiate surveys of the reptiles in their area to at least obtain baseline information on as many species as possible. We know less about natural reptile diseases than we do about amphibians, and we have less information on population sizes and species status. This is an area that needs critical attention.

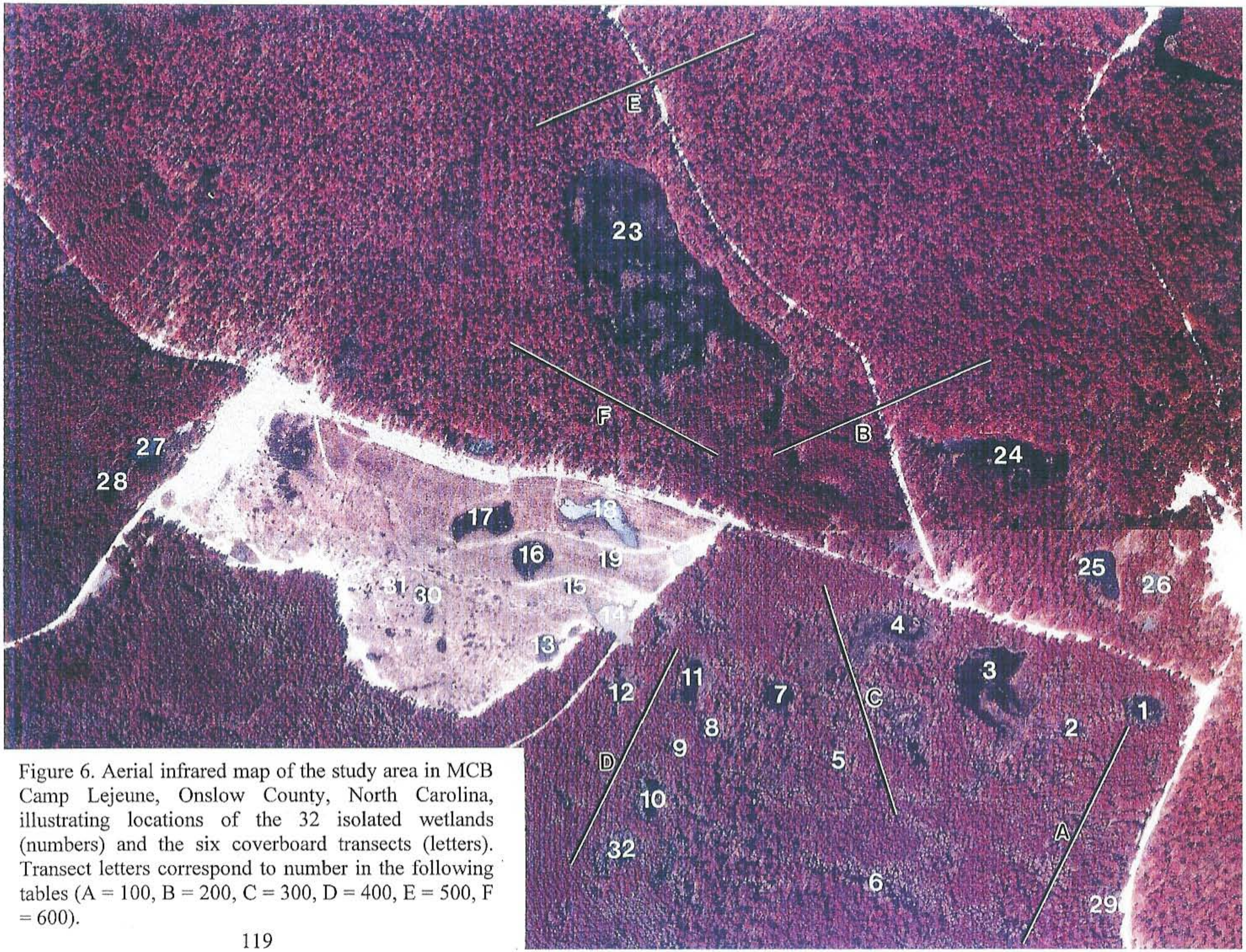

Figure 6. Aerial infrared map of the study area in MCB Camp Lejeune, Onslow County, North Carolina, illustrating locations of the 32 isolated wetlands (numbers) and the six coverboard transects (letters). Transect letters correspond to number in the following tables (A = 100, B = 200, C = 300, D = 400, E = 500, F = 600).

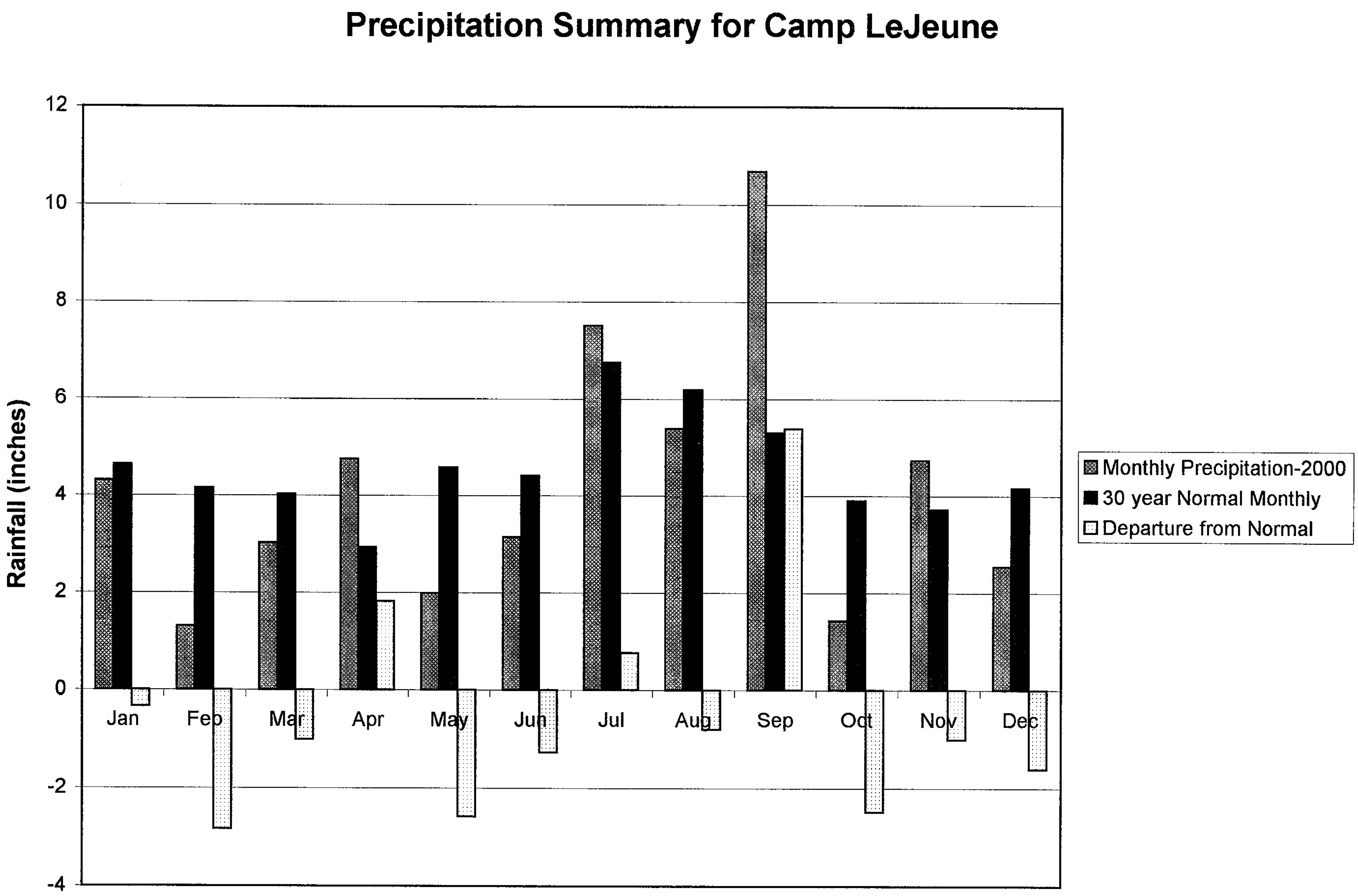

Figure 5. Monthly precipitation totals, 30-year averages, and departure from normal for Camp Lejeune, NC in 2000. Departure from normal is the difference between the monthly total for 2000 and the 30-year average. Data were from the USGS Drought Monitoring Program weather station located 1.3 miles East of the study area.

Table 50. Water chemistry (pH) values for selected isolated wetlands (limesinks and manmade pools) on MCB Camp Lejeune in 2000.

	Isolated Wetland Site																	
Month	1	3	4	7	8	9	10	11	12	15	16	17	18	23	24	27	28	32
March	7.06	6.38	6.96	5.03	4.78	5.25	5.18	5.19	5.48	6.02	6.52	6.73	7.89	5.18	6.74			4.71
April	6.38	6.57	7.32	4.90	4.74	5.25	5.08	4.89	5.37	5.26	5.94	5.69	7.96	4.81	7.49			4.87
May	6.69	5.71	6.81	4.60		5.07	4.80	4.64	5.17	4.94	6.36	6.15	7.94	4.66	5.73		6.44	4.77
June	6.65		8.07	5.56	5.88	5.05	5.63	5.25	5.29	4.83	6.30	6.00	7.74	4.74	5.95	7.71	6.40	5.42
July		6.29		4.79		4.93	4.79	4.86	5.22	6.78	5.75	7.08	8.92	5.13	6.03	8.82	6.77	
September	6.49	6.28	6.95	4.55	4.69	4.92	4.92	5.23	5.75	6.26	6.87	6.22	7.79	4.90	7.26	6.69	6.34	4.82
October	6.58	5.71	6.32	4.54	4.42	4.67	4.65	4.92	5.49	5.78	6.67	7.22	7.16	5.08	6.12	6.27	6.50	4.94

Table 51. List of amphibian species encountered in the study area on MCB Camp Lejeune, Onslow County, North Carolina in 1999 and 2000.

Anura (Frogs and Toads)	
Bufonidae:	
Bufo terrestris	Southern Toad
Hylidae:	
Acris gryllus gryllus	Coastal Plain Cricket Frog
Hyla chrysoscelis	Cope's Gray Treefrog
Hyla cinerea	Green Treefrog
Hyla femoralis	Pine Woods Treefrog
Hyla gratiosa	Barking Treefrog
Hyla squirella	Squirrel Treefrog
Pseudacris crucifer crucifer	Northern Spring Peeper
Pseudacris ocularis	Little Grass Frog
Pseudacris ornata	Ornate Chorus Frog
Microhylidae:	
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad
Pelobatidae:	
Scaphiopus holbrookii	Eastern Spadefoot
Ranidae:	
Rana catesbeiana	American Bullfrog
Rana clamitans melanota	Northern Green Frog
Rana sphenocephala utricularia	Southern Leopard Frog
Caudata (Salamanders)	
Ambystomatidae:	
Ambystoma mabeei	Mabee's Salamander
Ambystoma opacum	Marbled Salamander
Amphiumidae:	
Amphiuma means	Two-toed Amphiuma
Plethodontidae:	
Plethodon chlorobryonis	Atlantic Coast Slimy Salamander
Salamandridae:	
Notophthalmus viridescens dorsalis	Broken-striped Newt
Sirenidae:	
Siren intermedia intermedia	Eastern Lesser Siren

Table 52. Number of amphibians captured at Camp Lejeune in 2000 by life history stage.

	SEX/ LIFE HISTORY STAGE					
	Male	Female	Juvenile	unknown sex	Larvae	Total
Frogs						
A. gryllus	48	6	1		164	219
B. terrestris	3	3				6
G. carolinensis	6	11		5	27	49
H. chrysoscelis	10	2			189	201
H. cinerea	14	3		1		18
H. femoralis	46	33	4	3	99	185
H. gratiosa	47	2		5	277	331
H. squirella	123	115	27	23	68	356
P. crucifer		1			29	30
P. ocularis	2	2		2		6
P. ornata	2				1	3
R. catesbeiana	12	20	44		1591	1667
R. clamitans		1	1	1	114	117
R. sphenocephala	10	18	6		1391	1425
Salamanders						
A. mabeei	1	2		1	1	5
N. viridescens	72	57	2	4	203	338
P. chlorobryonis	4	5	1	11		21
S. intermedia			2		5	7
Total	400	281	88	56	4159	4984

Table 53. Species occurrence by sampling technique at Camp Lejeune in 2000.

	SAMPLING TECHNIQUE					
	Artificial Cover Transects	PVC Pipe Transects	Visual Encounter Surveys	Minnow Trapping	Dip Nets	Frog Call Surveys
Frogs						
A. gryllus			X	X	X	X
B. quercicus						X
B. terrestris	X		X			X
G. carolinensis	X		X		X	X
H. chrysoscelis		X	X	X	X	X
H. cinerea	X	X	X			X
H. femoralis		X	X	X	X	X
H. gratiosa		X	X	X	X	X
H. squirella	X	X	X			X
P. crucifer		X			X	X
P. ocularis	X					X
P. ornata	X		X	X		X
R. catesbeiana			X	X	X	X
R. clamitans				X	X	X
R. sphenocephala			X	X	X	X
Salamanders						
A. mabeei			X	X	X	
N. viridescens				X	X	
P. chlorobryonis	X					
S. intermedia				X	X	

Table 54. Number of amphibians captured in coverboard transects at Camp Lejeune in 2000.

	TRANSECT NUMBER						
	100	200	300	400	500	600	Total
Frogs							
B. terrestris	1		1				2
G. carolinensis	1		2	13			16
H. cinerea					1		1
H. squirella				1	1		2
P. ocularis		2		2			4
P. ornata				1			1
Salamanders							
P. chlorobryonis	3		1	6		1	11
Total	5	2	4	23	2	1	37

Table 55. Number of amphibians captured in PVC pipe transects at Camp Lejeune in 2000.

	TRANSECT NUMBER						
	100	200	300	400	500	600	Total
Frogs							
H. chrysoscelis			2				2
H. cinerea	1		3			3	7
H. femoralis	3	17	9	24	5	5	63
H. gratiosa				1			1
H. squirella	12	89	23	18	40	45	227
P. crucifer					1		1
Total	16	106	37	43	46	53	301

Table 56. Number of amphibians captured during Visual Encounter Surveys at Camp Lejeune in 2000. Abbreviations: Agr = *Acris gryllus*, Bte = *Bufo terrestris*, Gca = *Gastrophryne carolinensis*, Hch = *Hyla chrysoscelis*, Hci = *Hyla cinerea*, Hfe = *Hyla femoralis*, Hgr = *Hyla gratiosa*, Hsq = *Hyla squirella*, Por = *Pseudacris ornata,* Rca = *Rana catesbeiana*, Rsp = *Rana sphenocephala*, Ama = *Ambystoma mabeei.*

	Agr	Bte	Gca	Hchr	Hci	Hfe	Hgr	Hsq	Por	Rca	Rsp	Ama	Total
Site													
1					1		2				1		4
3	31										5		36
4		1			3		1	1			8		14
9											1		1
10										1			1
11	2									3			5
12			3				19	7		15			44
13						1				2			3
14										9	1		10
15										1			1
18					1					2			3
23	15				1	19	42			22	13		112
27			2		4		1			1	2		10
29			1	10				56			2		69
30									1				1
31		2									1		3
32												1	1
Total	48	3	6	10	10	20	65	64	1	56	34	1	318

Table 57. Number of amphibians captured in minnow traps at Camp Lejeune in 2000. Abbreviations: Agr = *Acris gryllus*, Hch = *Hyla chrysoscelis*, Hfe = *Hyla femoralis*, Hgr = *Hyla gratiosa*, Por = *Pseudacris ornata*, Rca = *Rana catesbeiana*, Rcl = *Rana clamitans*, Rsp = *Rana sphenocephala*, Ama = *Ambystoma mabeei*, Nvi = *Notophthalmus viridescens*, Sin = *Siren intermedia*.

Site	# of trapdays per site	Agr	Hch	Hfe	Hgr	Por	Rca	Rcl	Rsp	Amab	Nvi	Sin	Total
1	67			1				5	11		11		28
3	67						44	3	30		3		80
4	22				15								15
7	85						1	19	24		1		45
8	60							1	13				14
9	70							2	19				21
10	88						4	1	10	2	2	3	22
11	105						2	21	12		12		47
12	88				54		6	1	18	1	10		90
13	18							5	8				13
14	30						66		1				67
15	58	1					331	3	10				345
16	79						135	3	13		2		153
17	73						194	5	9				208
18	89						33	1	3				37
19	32						80	1	51				132
23	500	6	1		41		6	28	429		49		560
24	115	1	1		11	1	7		9		12		41
27	58						144		67				211
28	52						21		8				29
30	10										3		3
32	67						2	7	60		3		72
Total	1833	8	2	1	121	1	1076	106	805	3	108	3	2234

Table 58. Relative abundance of amphibians and predatory invertebrates in Site 1 at Camp Lejeune in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
H. chrysoscelis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00
H. femoralis	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00
R. catesbeiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
R. clamitans	22.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	4.55	41.67	25.00	0.00	0.00	0.00	0.00	0.00	15.00
N. v. dorsalis	27.27	8.33	10.00	5.00	0.00	0.00	10.00	5.00	0.00
Invertebrates									
Crayfish	0.00	8.33	50.00	25.00	0.00	0.00	5.00	40.00	50.00
Odonata larvae	31.82	25.00	25.00	60.00	0.00	0.00	5.00	10.00	5.00
Giant water bug	0.00	0.00	0.00	5.00	0.00	0.00	20.00	5.00	15.00
Pre. Diving beetle	4.55	8.33	30.00	10.00	0.00	0.00	15.00	0.00	0.00

Table 58. Relative abundance of amphibians and predatory invertebrates in Site 1 at Camp Lejeune in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
H. chrysoscelis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00
H. femoralis	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00
R. catesbeiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
R. clamitans	22.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	4.55	41.67	25.00	0.00	0.00	0.00	0.00	0.00	15.00
N. v. dorsalis	27.27	8.33	10.00	5.00	0.00	0.00	10.00	5.00	0.00
Invertebrates									
Crayfish	0.00	8.33	50.00	25.00	0.00	0.00	5.00	40.00	50.00
Odonata larvae	31.82	25.00	25.00	60.00	0.00	0.00	5.00	10.00	5.00
Giant water bug	0.00	0.00	0.00	5.00	0.00	0.00	20.00	5.00	15.00
Pre. Diving beetle	4.55	8.33	30.00	10.00	0.00	0.00	15.00	0.00	0.00

Table 59. Relative abundance of amphibians and predatory invertebrates in Site 15 at Camp Lejeune in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
A. gryllus	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00
R. catesbeiana	25.00	1350.00	633.33	80.00	80.00	290.00	0.00	0.00	85.00
R. clamitans	25.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	25.00	33.33	0.00	0.00	0.00	10.00	0.00	0.00	0.00
Invertebrates									
Crayfish	33.33	83.33	191.67	80.00	430.00	270.00	0.00	0.00	185.00
Pre. Diving beetle	8.33	33.33	16.67	0.00	0.00	0.00	0.00	0.00	0.00

Table 60. Relative abundance of amphibians and predatory invertebrates in Site 23 at Camp Lejeune in 2000 based on the minnow trap technique. Values are number of individuals per 50 trap nights.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
A. gryllus	0.00	0.00	0.00	0.00	0.00	5.00	1.00	1.00	0.00
H. chrysoscelis	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
H. gratiosa	0.00	0.00	0.00	2.00	5.00	5.00	29.00	21.00	1.00
R. catesbeiana	0.00	1.00	0.00	0.00	2.00	3.00	0.00	0.00	0.00
R. clamitans	25.00	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	15.00	149.00	206.00	37.00	13.00	23.00	2.00	0.00	0.00
N. v. dorsalis	30.00	13.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
Invertebrates									
Crayfish	19.00	77.00	124.00	266.00	123.00	91.00	62.00	58.00	66.00
Odonata larvae	2.00	3.00	11.00	28.00	6.00	8.00	3.00	7.00	5.00
Giant water bug	0.00	1.00	4.00	1.00	1.00	2.00	2.00	4.00	4.00
Pre. Diving beetle	4.00	112.00	60.00	61.00	25.00	41.00	14.00	6.00	1.00
Water scorpion	0.00	0.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00

Table 61. Number of amphibians captured in dipnets at Camp Lejeune in 2000. Abbreviations: Agr = *Acris gryllus*, Gca = *Gastrophryne carolinensis*, Hch = *Hyla chrysoscelis*, Hfe = *Hyla femoralis*, Hgr = *Hyla gratiosa*, Pcr = *Pseudacris crucifer,* Rca = *Rana catesbeiana*, Rcl = *Rana clamitans,* Rsp = *Rana sphenocephala*, Ama = *Ambystoma mabeei*, Nvi = *Notophthalmus viridescens,* Sin = *Siren intermedia.*

Site	# of sweeps per site	Agr	Gca	Hch	Hfe	Hgr	Hsq	Pcr	Rca	Rcl	Rsp	Ama	Nvi	Sin	Total
1	65	1	4	69				7			11		8		100
3	97	5							13	1	25				44
4	28	1	1			7					3		11		23
7	95	6									13		24		43
8	82	6	2	1	37		34	1			14		11		106
9	80	1							2		17				20
10	116							4			24		2		30
11	114	25											14	1	40
12	80	12	16	37	40	58							58	1	222
14	64								13		86				99
15	80	2							98		38				138
16	96	1			1				24	5			1		32
17	120	1							47		16		1		65
18	114	2						1	49		5				57
23	460	64		7		10			2	10	191		76		360
24	127	29		19		29		5	1		14		16		113
27	62			52					29		9		1		91
28	56		1						12	10			1		24
32	103	2	2	1	20	1	13	2	1		44	1	3		90
Total	(2039)	156	26	186	98	105	47	17	291	26	510	1	227		1690

Table 62. Relative abundance of amphibians and predatory invertebrates in Site 1 at Camp Lejeune in 2000 based on the dipnet technique. Values are number of individuals per 50 dipnet sweeps.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
A. gryllus	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00
G. carolinensis	0.00	0.00	0.00	0.00	0.00	15.00	5.00	0.00
H. chrysoscelis	0.00	0.00	0.00	0.00	0.00	230.00	115.00	0.00
P. crucifer	0.00	6.67	25.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	15.00	0.00	0.00	0.00	0.00	0.00	0.00	40.00
N. v. dorsalis	20.00	3.33	15.00	0.00	0.00	0.00	0.00	0.00
Invertebrates								
Crayfish	0.00	0.00	5.00	0.00	0.00	0.00	10.00	40.00
Odonata larvae	35.00	20.00	35.00	0.00	0.00	10.00	25.00	155.00
Giant water bug	0.00	0.00	0.00	0.00	0.00	15.00	0.00	0.00
Pre. Diving beetle	5.00	6.67	5.00	0.00	0.00	0.00	30.00	40.00

Table 63. Relative abundance of amphibians and predatory invertebrates in Site 15 at Camp Lejeune in 2000 based on the dipnet technique. Values are number of individuals per 50 dipnet sweeps.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians								
A. gryllus	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
R. catesbeiana	183.33	140.00	35.00	83.33	68.75	0.00	14.29	30.00
R. sphenocephala	91.67	0.00	0.00	0.00	0.00	0.00	7.14	30.00
Invertebrates								
Crayfish	25.00	20.00	25.00	25.00	75.00	5.00	7.14	10.00
Odonata larvae	0.00	10.00	0.00	4.17	25.00	5.00	0.00	0.00
Giant water bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
Pre. Diving beetle	0.00	0.00	5.00	0.00	0.00	0.00	0.00	25.00

Table 64. Relative abundance of amphibians and predatory invertebrates in Site 23 at Camp Lejeune in 2000 based on the dipnet technique. Values are number of individuals per 50 dipnet sweeps.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Amphibians									
A. gryllus	0.00	0.00	0.00	0.00	4.00	24.00	14.00	22.00	0.00
H. chrysoscelis	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00
H. gratiosa	0.00	0.00	0.00	0.00	0.00	5.00	0.00	5.00	0.00
R. catesbeiana	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
R. clamitans	2.50	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00
R. sphenocephala	18.33	36.00	93.00	25.00	2.00	10.00	0.00	3.00	0.00
N. v. dorsalis	4.17	1.00	0.00	4.00	11.00	17.00	3.00	35.00	0.00
Invertebrates									
Crayfish	20.00	44.00	41.00	32.00	14.00	31.00	1.00	19.00	21.00
Odonata larvae	16.67	2.00	5.00	6.00	19.00	3.00	15.00	19.00	30.00
Giant water bug	1.67	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Pre. Diving beetle	10.00	7.00	2.00	0.00	0.00	11.00	1.00	10.00	13.00
Water scorpion	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00

Table 65. Amphibian species in each of seven frog call monitoring stations on Camp Lejeune in 2000 identified by vocalizations (V). Abbreviations for each species in parentheses are for the following tables.

Species	Sites 1	3	12	18	23	24	29
Frogs:							
Acris gryllus gryllus (Agr)	V	V	V	V	V	V	V
Bufo terrestris (Bte)	V	V	V	V	V	V	
Gastrophryne carolinensis (Gca)	V		V			V	
Hyla chrysoscelis (Hch)	V	V	V	V	V	V	
Hyla cinerea (Hci)	V			V	V		
Hyla femoralis (Hfe)	V	V	V		V	V	V
Hyla gratiosa (Hgr)			V		V	V	
Hyla squirella (Hsq)	V	V	V	V	V	V	V
Pseudacris crucifer crucifer (Pcr)	V	V	V		V	V	
Pseudacris ocularis (Poc)		V	V	V		V	V
Pseudacris ornata (Por)		V	V	V			
Rana catesbeiana (Rca)	V	V	V	V	V	V	
Rana clamitans melanota (Rcl)		V			V	V	V
Rana sphenocephala utricularia (Rsph)	V	V	V	V	V	V	V

Table 66. Seasonal variation in timing of male frog vocalizations at Site 1 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp
February 27										V				V
March 5										V				V
March 12	V									V				V
March 19	V									V				
March 26	V									V				V
April 2	V									V				
April 9		V								V				V
April 16										V		V		V
April 23								V		V				V
April 30	V		V	V		V								V
May 7	V			V		V								V
May 14	V	V		V										V
May 21	V			V		V								V
May 28	V			V		V								
June 4	V			V		V								
June 11				V										V
June 18	V			V										V
June 25	V													
July 2	V		V	V										V
July 9	V			V										V
July 16	V			V										V
July 23	V			V										
July 30	V			V										V
August 6	V													
August 13														
August 20														
August 27	V													
September 3														
September 10														

Table 67. Seasonal variation in timing of male frog vocalizations at Site 3 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species														
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Por	Rca	Rcl	Rsp
February 27	V									V					
March 5	V									V					
March 12	V									V					
March 19	V									V	V				V
March 26	V									V	V				V
April 2	V									V					V
April 9	V	V				V						V			
April 16	V														V
April 23	V	V						V			V				V
April 30				V		V		V							V
May 7	V			V		V									V
May 14	V			V		V		V							V
May 21	V	V												V	V
May 28	V			V		V									V
June 4	V														V
June 11	V			V		V		V							
June 18	V														V
June 25	V												V		
July 2	V			V		V		V							V
July 9	V														
July 16	V														V
July 23	V														V
July 30	V												V		V
August 6	V														
August 13				V											
August 20															
August 27	V					V									
September 3															
September 10															

Table 68. Seasonal variation in timing of male frog vocalizations at Site 12 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species														
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Por	Rca	Rcl	Rsp
February 27											V		V		V
March 5	V										V	V			
March 12	V										V				V
March 19	V									V	V		V		
March 26	V									V	V	V			
April 2	V									V					V
April 9										V	V				V
April 16	V					V				V			V		
April 23								V		V	V				V
April 30			V		V	V	V								V
May 7	V						V						V		V
May 14	V				V		V				V				
May 21	V					V									V
May 28													V		V
June 4	V														V
June 11	V	V					V				V				V
June 18	V						V								V
June 25													V		
July 2	V						V	V					V		
July 9	V			V									V		V
July 16						V							V		
July 23								V					V		V
July 30	V					V									
August 6	V							V							
August 13															
August 20															
August 27													V		V
September 3													V		
September 10															

Table 69. Seasonal variation in timing of male frog vocalizations at Site 18 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species														
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Por	Rca	Rcl	Rsp
February 27												V	V		
March 5													V		
March 12	V												V		V
March 19	V												V		V
March 26	V												V		
April 2	V												V		
April 9	V	V											V		
April 16	V												V		
April 23		V											V		V
April 30	V				V								V		
May 7	V												V		V
May 14	V				V								V		V
May 21	V				V								V		V
May 28	V										V				
June 4	V							V					V		
June 11	V												V		
June 18													V		V
June 25	V				V			V					V		V
July 2													V		V
July 9													V		
July 16	V												V		
July 23	V												V		
July 30		V		V									V		
August 6													V		
August 13															
August 20															
August 27															
September 3															
September 10															

Table 70. Seasonal variation in timing of male frog vocalizations at site 23 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp
February 27	V									V				V
March 5	V									V		V		
March 12	V	V								V				V
March 19	V									V		V		V
March 26	V									V				V
April 2	V									V				V
April 9	V									V		V		V
April 16	V							V		V				V
April 23	V	V				V				V				V
April 30				V		V	V					V		V
May 7	V			V	V		V					V		V
May 14	V				V		V	V				V		V
May 21	V			V	V		V							V
May 28	V						V						V	V
June 4	V					V	V					V		
June 11	V					V	V					V		V
June 18	V				V	V	V							V
June 25	V					V	V					V		
July 2	V				V		V							V
July 9	V						V							V
July 16	V					V	V							V
July 23	V				V		V							V
July 30	V						V	V						V
August 6	V						V					V		
August 13	V						V							
August 20														
August 27														
September 3														
September 10														

Table 71. Seasonal variation in timing of male frog vocalizations at Site 24 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp
February 27										V				
March 5										V		V		V
March 12	V									V		V		V
March 19	V									V				V
March 26	V									V		V		V
April 2	V	V								V				
April 9										V		V		V
April 16										V		V		V
April 23		V				V				V				V
April 30				V			V	V						V
May 7	V						V	V				V		V
May 14	V		V			V	V						V	V
May 21	V						V					V		V
May 28	V						V							V
June 4	V						V							V
June 11	V	V				V	V					V		V
June 18	V						V					V		V
June 25	V			V			V				V			V
July 2	V			V			V					V		V
July 9	V						V							
July 16	V						V					V		V
July 23	V						V					V		
July 30	V					V	V					V		
August 6	V						V							
August 13	V													
August 20							V							
August 27				V			V							V
September 3														
September 10														

Table 72. Seasonal variation in timing of male frog vocalizations at Site 29 on Camp Lejeune for 2000. Abbreviations are as in Table 65.

	Species													
Week of	Agr	Bte	Gca	Hch	Hci	Hfe	Hgr	Hsq	Pbr	Pcr	Poc	Rca	Rcl	Rsp
February 27														V
March 5														V
March 12														V
March 19														
March 26														V
April 2														V
April 9	V													V
April 16														V
April 23														
April 30														
May 7						V		V			V			
May 14														
May 21						V		V			V			V
May 28						V		V						V
June 4														
June 11						V								V
June 18														V
June 25													V	
July 2														
July 9														
July 16														
July 23														
July 30														V
August 6								V						
August 13														
August 20														
August 27														V
September 3														V
September 10														

Table 73. Number of amphibians marked at Camp Lejeune in 2000 by life history stage.

	SEX AND LIFE HISTORY STAGE			
	Male	Female	Juvenile	Total
Frogs				
B. terrestris		3		3
H. chrysoscelis	10	2		12
H. cinerea	12	3		15
H. femoralis	36	18	3	57
H. gratiosa	46	1		47
H. squirella	87	45	6	138
R. catesbeiana	10	15	32	57
R. sphenocephala	7	15	4	26
Total	208	102	45	355

Table 74. Recapture locations and minimum distances moved for frogs recaptured on Camp Lejeune in 2000.

Species	Location Marked	Location Recaptured	Distance (m)
H. squirella	200A	200B (pvc 222)	70
H. squirella	200B	200A (pvc 207)	90
H. squirella	400B	400A (pvc 409)	70
H. squirella	600A	600B (pvc 627)	120
H. squirella	100B	100B (pvc 103)	130
R. catesbeiana	Site 14	Site 13	40

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